TP 5257E

OPERATIONAL DYNAMICS

MV ARCTIC

DATA ACQUISITION SYSTEM

REVIEW REPORT

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17. Abstract

The report presents a review and commentary on the operation and maintenance of the data acquisition system which was installed on the M.V. Arctic to record the vessels performance in ice. Operating and maintenance experience was obtained over three shipping seasons 1979, 1980 and 1981.

The report contains a general description of the data acquisition system as background information. Each component of the instrumentation system - the computer, the CCTV and the sensor system - is addressed in separate sections of the report. Conclusions on the operational effectiveness of the respective system components are reached. Recommendations are made for guidance in future system design where appropriate.

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17. Résumé

Ce rapport passe en revue et commente l'exploitation et l'entretien du système de saisie des données, installé à bord de l'arctic pour enregistrer le comportement de ce navire dans les eaux chargées de glaces au cours des trois saisons de navigation de 1979, 1980 et 1981.

Après avoir rappelé les caractéristiques générales du système, le rapport traite séparément des trois principaux éléments: ordinateur, télévision en circuit fermé et réseau extensométrique. Enfin, il tire des conclusions sur l'efficacité constatée des composants et formule des recommandations de nature à aider l'étude d'un système plus évolué.

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1. INTRODUCTION

This report presents a review and commentary on the operational and maintenance experience encountered during the operation of the data acquisition system aboard the MV ARCTIC over three shipping seasons: 1979, 1980 and 1981. This data acquisition system is designed to record the ship's operational experience while navigating in ice in terms of prevailing conditions and the ship's performance and response. The instrumentation system comprises a central computer and sensor array supported by a closed circuit television system. The sensor system consists primarily of an array of strain gauges attached to the hull structure and configured to help determine icebreaking stresses on the ship using finite element analysis. Special purpose sensors monitor the steering and propulsion system and equipment on the navigation bridge. Each sensor signal is sampled and digitized at a predetermined rate. All data is stored on a magnetic tape for subsequent analysis ashore.

The report is partitioned into sections. Following this introduction, the next section of the report gives an overview of the data acquisition system, briefly describing the function of the three main sub-systems, namely: the computer, the closed circuit television, and the sensors. Subsequent sections each address a particular sub-system or major component of a sub-system. Each section reaches conclusions on the operational effectiveness of the respective component and, where appropriate, recommendations are made for guidance in future designs. In addition some overall conclusions and recommendations are provided in the final section of the report.

2. SYSTEM DESCRIPTION

2.1 Functional Design

The instrumentation system aboard the mv Arctic was installed when the ship was commissioned in 1978 for the purpose of recording the vessel's performance in ice. The installation consists of three main functional groups as follows:

- A computer system comprising a mini-computer, disk drives, tape drives, and printer-terminals.
- A closed circuit video system comprising a television camera, video recorder and video monitor.
- A sensor system comprising an analog/digital interface for the computer, data bus and junction boxes serving a wide variety of sensors.

Figure 2.1 gives a block diagram of the data acquisition system and Figure 2.2 shows the layout of the system within the ship. Data records are taken from five specific sensors groups as follows:

- Hull Structure
- Propulsion
- Ship Motions
- Auxilliary
- Environment

Data gathering is controlled by the central computer that monitors and directs operations within the system from the ship's laboratory. Sensors, located at key points on the ship, continuously monitor the operation and response parameters of the ship's performance in ice. The system samples the sensors according to preset requirements and stores the data on tape for subsequent analysis. Simultaneous video records are also obtained to document environmental conditions.

2.2 Computer System

The instrumentation system is controlled by the mini computer together with its associated peripheral equipment and software.

There are two distinct computer programs - the data acquisition program and the playback program. Only one can operate at any given time.

a) The data acquisition program has been designed for fully automatic operation and to be run by non-computer oriented personnel with a minimum of training. It is designed to:
   i) collect sensor data and store it on tape,
   ii) permit limited viewing of the data via hardcopy printout while it is being collected.

   The operator is free to select the sampling pattern to suit any particular requirement. For example, in monitoring he may be interested in one channel only, while during actual ice trials he may wish to record all available data. He may also select the rate at which any channel is sampled and the mode of sampling - Peak Holding or Real; Recording or Standby.

   Once data gathering is started, the sampling of sensors is continuous and the recording of data to tape is optional.

   A continuous recording mode may be selected, whereby all data collected is written to tape. This may be useful for calibration and testing, but in general will record masses of uninteresting data. Consequently, a standby option has been provided. In the standby mode, any or all sensors may be assigned "alarm limits" to distinguish interesting values from uninteresting ones. As long as no sensor exceeds its alarm limits, no data is recorded on tape, although the sensors are sampled continuously. If any sensor exceeds its alarm limit, recording is started and continues for a pre-selected interval (30 seconds, for example), after which the program reverts again to standby, sampling but not recording. In standby mode, one second's worth of data is recorded to tape every hour, to provide static load and other information.

The configuration of the system permits the use of 256 data channels. Advantage has been taken of the speed of the computer to use time division multiplexing whereby data channels are interrogated successively for a short period each. Seven sampling rates are available provided the total number of samples does not exceed 1765. Available rates may be applied to any sensor bearing in mind the total rate limitation, as follows:

	Prior to Oct. 1980		After Oct. 1980	
Rate 1	1	sample/10 sec	1	sample/10 sec
" 2	1	" /sec	1	" /sec
" 3	10	" /sec	10	" /sec
" 4	40	" /sec	50	" /sec
" 5	100	" /sec	100	" /sec
" 6	250	" /sec	500	" /sec
" 7	1000	" /sec	1000	" /sec

Until the operator halts data gathering, the sampling and recording of data takes precedence over other functions. Nevertheless, it is possible to verify operation of the system via two printout options, monitoring and logging, which operate concurrently with data gathering:

Monitoring

Any sensor may be selected for continuous printout and a value is typed periodically at a rate dependent on printer speed limitations. This is useful for checking a sensor which may be expected to vary over a period of seconds. It is not capable of reflecting changes occurring at faster rates due to printer speed limitations.

Logging

In the absence of monitoring, logging is used. One value for every sensor is typed at an interval selected by the operator (every two hours, for example). This is useful as a permanent record that the system was working, and also as a check on the proper functioning of the sensors. All values exceeding their alarm limits are flagged on the printout. A careful check should be made of readings on sensors that are not alarmed to ensure that they are reasonable.

b) The playback program provides a limited capability for reviewing recorded data. The tape may be searched by alarm limits, or by date and time, to locate an area of interest. When this is located, the operator may proceed in one of three modes:

i) Monitoring mode prints all values or every Nth value (N selected by the operator) of one selected sensor. Statistics are also accumulated.

ii) Dump mode prints every value recorded. This mode will be used only for debugging and system verification, since it takes up to an hour to print one second's worth of data. Statistics are also accumulated.

iii) Statistics mode: No printout occurs as the tape is read. Statistics are accumulated.

Analysis of accumulated statistics is intended to be carried out ashore. A description of the computer is given in Section 3.

2.3 Closed Circuit Television System

As an additional feature, a closed circuit television system has been included. Its purpose is to provide a visual record of environmental conditions prevailing during ice encounters. A video monitor is also provided on the bridge for the benefit of the ship's operating personnel.

The camera is normally mounted on top of the forward masthead. In this position it is remotely controlled, either manually or automatically. Alternative mounts are provided, two on the forecastle, starboard side and one at the stern on the poopdeck. These three locations have no provision for automatic operation.

A video recorder is provided on which the display may be recorded at any time. In the automatic mode, the system is activated by computer command related to the alarm level. Time/date information appears on every frame to permit correlation of video and data tape records.

For details of the Closed Circuit Television System see Section 4.

2.4 Sensor System

The sensor system consists of groups of sensors connected to seven junction boxes, which contain power supplies for sensor excitation (where required) and printed circuit boards for signal conditioning (one for each sensor). These boxes are interconnected by a data bus: a 15-pair armoured cable forming a loop configuration and thus providing circuit redundancy to protect the system from data loss in the event of a cable break. The data bus connects to a main interface and thence to the computer system both of which are located in the laboratory on the port side aft.

a) Sensors: There are five sets of sensors grouped to record data on:

- Hull Structure
- Propulsion
- Ship Motions
- Auxilliary Systems
- Environment

The most important measurements, as well as the most difficult to obtain, relate to the hull structure, where measurements of strain and temperature are required. A comprehensive theoretical study was carried out in order to decide the number and location of the strain gauges necessary to provide suitable data. The gauges were installed during the final stages of construction of the ship and during refits as necessary. The hull instrumentation is described in Section 5.

Measurements of propulsion machinery parameters are required where they relate directly to the performance of the ship. The measurements include engine RPM, shaft torque, propeller command and response, fuel rack and so forth. The propulsion machinery instrumentation is described in Section 6.

Measurements of ship motion relate to ship's speed, pitch and roll, ship's head, rudder command and response, heave, surge and sway. The measurement of these parameters is described in Section 7.

The ship was fitted with a pneumatic thrust/bubbler system. Instrumentation was provided to monitor the performance of this auxiliary equipment. This instrumentation is described in Section 8.

Certain environmental conditions are entered into the system by manual input through selectors located on the ship's bridge. Readings from conventional instruments are entered into the system through decade selectors. These readings relate to air temperature, relative humidity, barometric pressures, visibility, cloud cover and ice cover. Section 9 elaborates on these inputs.

b) Junction Boxes and Data Bus: The junction boxes are numbered from 1 to 7 and contain a total of 16 groups or bins, each bin contains 16 signal conditioning (amplifier) cards which, in turn, each serve a specific data channel. The distribution of the junction boxes is as follows:

Junction Box	Location	No. of Bins
1	Forecastle	2
2	"	3
3	"	3
4	"	3
5	Bubbler Compt.	1
6	Engine Room	2
7	Nav. Bridge	2

Addressing of an individual sensor is by bin and then by channel within the selected bin. However, for simplicity channels have been numbered 1 to 256.

The signal conditioning card for each channel junction box includes a unique code or "address" which responds to a specific signal from the computer. A digital, high-level, parallel addressing system has been used to select the individual channels, and eight of the data lines permit a total of 256 unique codes to be handled. A ninth line is available for future expansion of the system.

Sensor inputs are amplified by the signal conditioning cards. At any instant, only one output is on the data bus to the laboratory. Section 10 describes the junction boxes and data bus.

c) Interface Panel: The interface panel links the data bus to the computer system. It performs several functions, as follows:

i) Amplification of low power "address" signals from the computer by driver circuits to full bus power level.

ii) Analog to digital conversion of data outputs signals.

iii) Alarm level setting of strain gauge channels.

iv) "Fail safe" completion of timing in event of a conversion failure.

These are dealt with in more detail in Section 10.

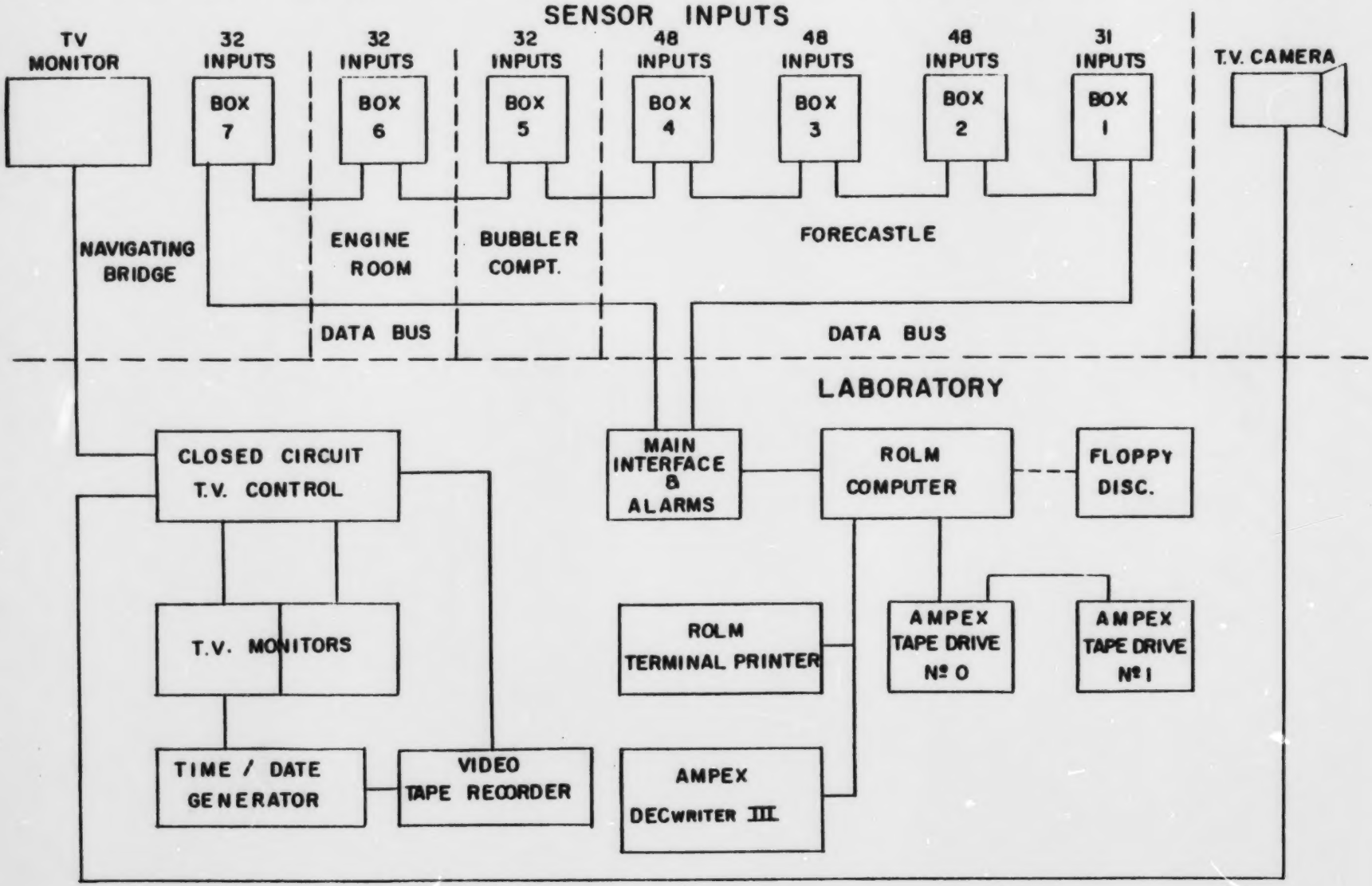


FIGURE 2.1 BLOCK DIAGRAM OF DATA ACQUISITION SYSTEM

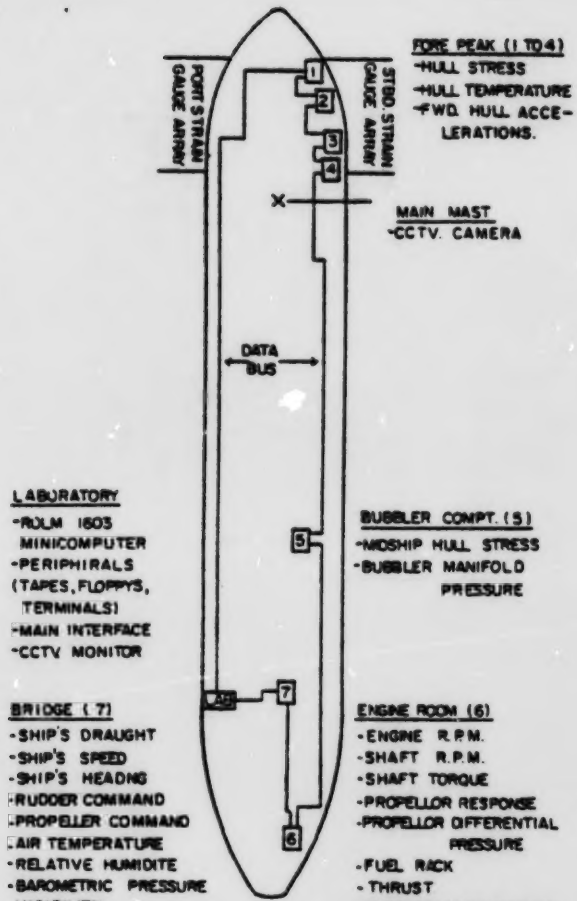


FIGURE 2.2 LAYOUT OF DATA ACQUISITION SYSTEM

3. COMPUTER AND PERIPHERALS

3.1 General

The computer system installed on the MV Arctic comprised four major components as follows:

Rolm 1603A, Central Processing Unit
AED 6200, Floppy Disk System
Ampex TMA, Magnetic Tape Drives
Rolm/Data General, Dasher Terminal Printers.

The above equipment is interfaced and interconnected as shown in Figure 2.1 of the previous section. In order to provide an adequate fail-safe capability for system redundancy each of the above components was duplicated in the installation.

3.2 Computer System Capability

The instrumentation system is controlled by the Rolm computer and the configuration of the system permits the use of 256 data channels of which 212 were used originally. The various operating modes are described in Section 2 of this report. The computer and its associated software provides for the following:

- sensor to channel assignments
- sensor addressing control
- sampling and sequence control
- real time data recording
- data conversion to engineering units
- channel monitoring on demand
- statistical and averaging computations

When the system was designed and installed in 1978, it was expected that the acquisition capacity would be in the region of 2850 samples per second. This figure represented the anticipated total sampling capacity of the system against which appropriate sampling patterns of the some 200 channels could be arranged choosing channel rates varying between between 1 to 1000 samples per second. Early in 1979, the first season of operation, it was discovered that the above capacity was not being achieved. Progressive tests were conducted with increasing sampling loads until it was concluded that the actual capacity was approximately 1765 samples per second.

Estimation of total system capacity is fundamental to this type of real time computer application where a specified sequence of events has to be performed in a specified time period, namely one second. The sequence has to be repeated each second and hence the load imposed on the system must not exceed the system's real-time capacity. An examination on the system's capacity is made in Table 3.1, in which it is estimated that each sample collected imposes the following real-time demands on the system.

Computer processing time:	315	microseconds per sample
Sensor addressing time:	103	" " "
Tape recording time:	162	" " "
Total acquisition time:	580	" " "

Based upon the above, it is estimated that the total system capacity is approximately 1725 samples per second which agrees well with the figure of 1765 samples per second found from system trials.

It is also evident from the above times, that action to increase system capacity would start best with a computer having a faster CPU core cycle time. This is possible with the present generation of mini-computers which are several times faster. Further improvements in system capacity could be obtained in sensor addressing and tape recording. It is interesting to note, however, that with a rating of 60 kilobytes per second the tape drives still compare favourably with more recent equipment. Newer installations would tend to incorporate fast disk drives rather than slower and more space consuming tape drives for recording purposes.

3.3 Description of Equipment and Maintenance Experience

3.3.1 Rolm 1603A Central Processing Unit

Description:

The model 1603A is a 16-bit general purpose computer designed for severe environment applications. The computer's memory consists of a 32K core maximum memory capacity. Included with the system is a full range of diagnostic software, a real-time clock, an extended arithmetic unit and up to six input/output interface modules. A front-end control panel could be used to direct all operations needed for the necessary operation of the CPU. The computer has a capacity of 61 external devices although the system only used five at any one time. All equipment was originally tested so as to minimize service requirements. Under extreme conditions the processor could operate between -55°C to 95°C and up to a height of 25,000 m. Based on a 1.2 microsecond cycle time the computer is rated at 833KHz.

Operation:

The processor has worked exceptionally well throughout and some reported problems are listed in Table 3.2(a).In general, the computer has crashed when overloaded but this is a software rather than hardware problem. Even in 1983, after some six years of use, the CPU is fully functional.

3.3.2 Ampex TMA Tape Drives

Description:

The model TMA low speed tape transport system has a capacity of 800 BPI at 75 ips. The tape drives allow for 9 track 800 m (2400 ft.) magnetic tapes with NRZI data electronics which were included to be IBM compatible. The TMA transport utilizes two,side-by-side, vacuum buffer columns for tape storage in a precision tape path with manual tape loading being standard. The maximum capacity for this system would be 60,000 bytes/second.

Operation: The tape drives have given reliable service and have been worked hard over six years. Some reported problems are provided in Table 3.2 (b). In 1983 the most frequent problems were connected with tape loop vacuum channels due to faulty pressure differential switches. Replacement parts are now almost unobtainable.

3.3.3 AED 6200P Floppy Disk Drives

Description:

The AED 6200P is a double density floppy disk system. The 6200P cabinet contains the formatter with control logic for up to four drives although only drives A and B are operational. It performs all functions related to Drive Selection, Head Positioning, Seek Verification, Data Formatting and Error Checking. It is therefore very easy to interface to most other mini computer models.

Operation:

The floppy disk drive has worked well throughout the system operating period. Some minor problems are listed in Table 3.2 (c). Regular cleaning and maintenance is required for satisfactory performance.

Terminal Printers:

Description:

The Rolm model 3315 terminal printer is built by Data General Corp. as a 6040 Dasher Terminal. It has a standard typewriter keyboard with 96 characters upper/lower case ASCII format. It offers 30/60 cps with switch selection. Width selection is from 4 to 15 inches and handles up to six-part forms.

Operation:

Apart from cleaning, few operating or maintenance problems - see Table 3.2 (d).

3.4 Commentary and Recommendations

The design of a data acquisition system starts from decisions on the following quantitative criteria:

- The volume of information required
- The number of sensors to be used
- The frequency of data sampling.

These criteria become the basis of the program which the system's computer has to accommodate in real time. The Rolm computer with a rating of 0.8 MHz was unable to accept a data requirement much in excess of 1765 samples per second. This placed a noticeable limitation on the comprehensiveness of data collection where more than 200 channels were being sampled. For example, structural sensors require a rate of about 20 samples per second which already could not be achieved with a total array of about 170 structural channels.

If a future system is to be designed and if such an extensive array of sensors is to be used, then a higher rated computer would be needed. Existing technology can accommodate such needs ranging from Apple computers at 1 MHz up to Hewlett Packard Series 200 computers at 8 MHz. The latter has eight times the rating of the Rolm. Data storage on disks also provide speed and capacity advantages.

Table 3.1: System Load Estimate

1. Tape Drives

   2 data blocks per second
   Each block full at 4096 words with 2 bytes/word.
   Total Load = 2x4096x2 = 16,384 bytes/sec

   Max capacity 800BPI x 75IPS = 60,000 bytes/sec

   Drive utilization = $\frac{16,384}{60,000}$ = 0.28 seconds

2. CPU

   Average program load per sample
   = 150 instructions x 2.1 microseconds

   = 315 microseconds/sample

3. Sensor A/D

   Average address settling time = 103 microseconds/sample

Summary:

CUP Load	=	315 microseconds/sample
Sensor A/D	=	103 microseconds/sample
Sub total	=	418 microseconds/sample
Available time	=	1.0 second less Tape Drive Time
	=	1.00 - 0.28 = 0.72 seconds
	=	720,000 microseconds
System Capacity	=	$\frac{720,000}{418}$ = 1725 samples/second

Table 3.2: Computer System Maintenance History

(a) Computer

Date	Freq	Problem	Action
May 1979	1	Computer halted each time bubbler was turned on due to a brief drop in AC voltage.	Problem would be solved with proper software.
June 1981	0	Computer system was giving problems - no specifics.	
	0	When loading data acquisition program computer run light goes out or address lights go out.	Possibly related to other equipment. In this case a faulty CUP was causing the problem.
August 1981	0	When computer was logging data with acquisition program execution would stop. CUP board was exchanged with spare computer board and faulty board was sent for repairs.	CUP board malfunction.
		It was realized that the maximum sampling rate was 1765 samples/second	N/A
		It was noted that computer operated with only one tape drive.	N/A
Sept. 1981	2	Problems still occurred when more than 1600 samples/second were recorded. Fatal I/O errors would halt the processor.	Attributed to tapes D5, D6, D7.
	0	Computer main frame over heated above 70°F room temperature. This problem was only reported once. Rolm specs indicate a standard operating range between 0° to 65°C.	Should run properly around 68°F (20°C).

(c) AED Floppy Disk Drive

Date	Freq	Problem	Action
August 1981	2	Floppy read/write heads should be cleaned-felt pads should be changed every 6 months during regular usage. Major cause of problems.	Clean with isopropyl alcohol regularly Run diagnostic tests.
August /83	1	Smoke coming from rear fans. Seemed to have been the transformer. Was found to have been a bridge on main power board.	Solder new bridge into board - this problem should not occur again.

(b) Tape Drives

Date	Freq.	Problem	Action
August 1979	1	Tape drive ø not working, required a new belt and adjustment.	Change motor belt and adjust accordingly.
June 1979	2	Both tape drives were not functioning properly. Malfunction not reported. When checked by servicemen , all was functioning.	N/A
June 1980	3	Request to clean tape drives and importance of this service.	Clean heads with isopropal alcohol and clean area.
June 1981	1	Drive 1 giving write errors.	Adjust with oscilliscope.
		Daisy-chain between tape drives was causing computer problems.	Back check - in this case the CPU was faulty.
Sept. 1981	1	The problem was a faulty CUP board discovered by Rolm and Ampex agents.	
August 1981		Report of Drive ø not functioning properly because of loading problems from vacuum chambers. Also problems in running tapes.	Adjust screw on PEB in rear of machine - or tapes are bad.
	0	Rewind command was disconnected from the system and the system seemed to run more effectively.	N/A
		Tape drive vacuum pump shuts down on drive ø, and tape gets tangled.	A faulty triac in the main power assembly should be checked and press stop/reset switch to stop tape movement.
			Tape could be bad.

(d) DGC (Dasher)

Date	Freq	Problem	Action
1981	0	End of paper fault, doesn't clear after paper refilled	Repaired by servicemen - faulty switch.

4. CLOSED CIRCUIT TV SYSTEM

4.1 System Description

A CCTV system is included as an adjunct to the data gathering system. Its functions are:

a) to provide a visual record of the ice interaction with hull, which can later be correlated to the strain gauge readings;

b) to provide general visual information concerning the environmental conditions, such as visibility and ice and snow coverage;

c) to automatically provide a 180^0 pan of the ship surroundings when triggered by the computer.

A video monitor is provided on the bridge for the use of the ship's navigating personnel. Two video monitors located in the laboratory are provided to enable review of video tapes independently of the monitor projecting images direct from the cameras.

The camera is normally mounted on top of the forward masthead. In this position it is remotely controlled, either manually or automatically. The control selections are: Iris open, zoom in, focus near, iris close, zoom out, focus far, tilt up, tilt down, pan stbd, pan port, camera on and blower on. Alternate mounts are also provided, two on the forecastle, starboard side, and one at the stern on the poopdeck. These three locations have no provision for remote control.

A video recorder is provided, on which the display may be recorded at any time. In the automatic mode, the system is activated by computer command related to alarm levels. Time/Date information appears on every frame to permit correlation of video and data tape records. Figure 4.1 illustrates the initial installations of the CCTV system. Table 4.1 lists the components of the system.

4.2 Maintenance Experience

On three separate occasions the CCTV system was damaged and required extensive repair. Early in 1979, steam escaping from a ship's line damaged the cable to the camera and subsequently required replacement of circuit components in the camera.

Later in 1979, damage to the ship's bow required repair to the video connections for the CCTV and repairs to the mounting area for the camera. Finally, in 1981 a crane damaged the CCTV control cable located on the deck and repair to this cable was again required.

Prior to the June trials of 1979 it was discovered that salt water was getting into the camera and damaging the receiver. Additionally, the camera gear box had siezed. Repairs were made to the receiver and the grease used in the gear mechanism was replaced with a grade suitable for cold weather operations.

Through 1979 and 1980 it was apparent that the environmental housing of the video camera was not suitable to the environment encountered at the bow of the MV Arctic. Constant maintenance was required to combat the corrosion on the camera's electronic parts.

By the beginning of the 1981 season both camera and housing required replacement. A second camera was added to the system at that time to monitor conditions over the side of the ship during trials. The unit is a Panasonic Low Light Model WV 1050A contained within a modified Vicon environmental housing.

Both cameras required attention during the 1981 voyages. The masthead camera iris controls malfunctioned due to a failed transistor; the side camera required setting up in the ship's laboratory before a reasonable picture could be obtained.

Video tapes from the system played back on the monitors after the monitors had been removed from the ship exhibit severe tracking mismatch at certain tape speeds. Tracking mismatch occurs when the speed of the playback equipment cannot be matched to that of the recording equipment, resulting in a poor quality image. Excessive component wear could produce this effect.

4.3 Commentary and Recommendations

The physical deterioration of the exposed CCTV equipment was so severe that all problems relating to the equipment malfunction must logically stem from the failure of the environmental enclosures used to adequately protect the electronic equipment. Air vents existed in the environmental enclosures used, providing ready access for the corrosive, salt-laden humid atmosphere common to a ship's environment. A more stringent specification for environmental enclosures should be used for future systems.

The CCTV tape provides the only objective record of ice cover. Operators input ice cover data on a scale of 1 to 10 into the data acquisition system via a decade switch setting, a written log is also kept. However, both these records are subjective and are not automatically recorded at ice encounter. The additional cost involved in getting an appropriate environmental enclosure for the CCTV would enhance the accuracy of the ice cover data records.

Table 4.1: Components of the CCTV System

PANASONIC Model WV-1050 Television Camera

CANON TV Zoom Lens J6 X 12REA (DC)

VICON Model V106AC Auto Iris and Zoom Lens Control

VICON Model V800H Environmental Enclosure
complete with Model V800-H Heater
Model V800-B Blower

VICON Model V300-115PT Pan and Tilt Drive

VICON Model V110PT Pan and Tilt Controls

PANASONIC Model NV-8030 Time Lapse Video Tape Recorder

PANASONIC Model TN-932 "Type 9" High Resolution Monitor TV

PANASONIC Model WV-5301 Video Monitor

PELCO Model TDG-100 Video Time/Date Generator

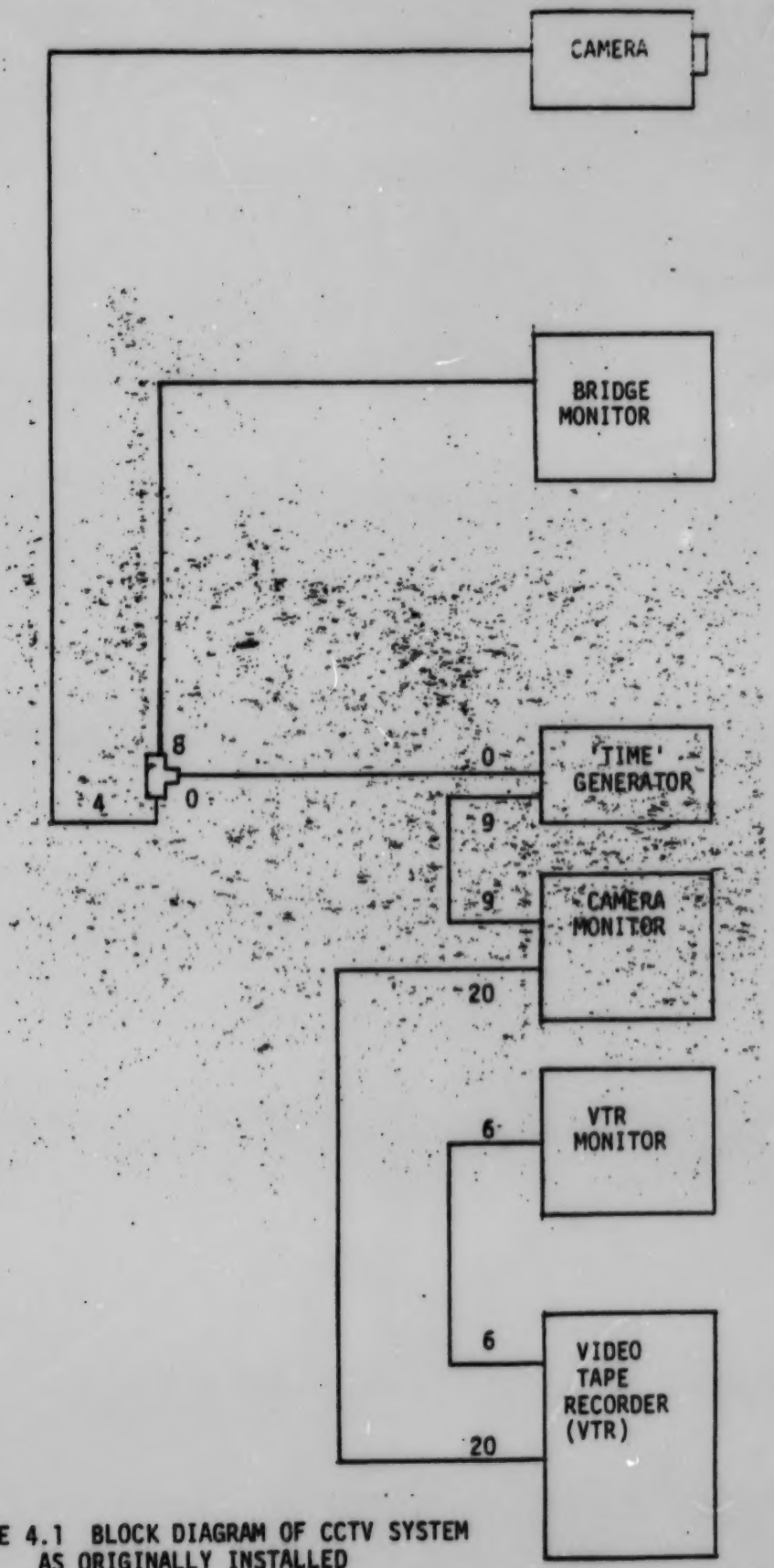


FIGURE 4.1 BLOCK DIAGRAM OF CCTV SYSTEM AS ORIGINALLY INSTALLED

5. HULL STRUCTURE SENSORS

5.1 Purpose

The purpose of the hull structure sensors is: to measure strain at selected points on the hull during operations in ice in order to appraise the ability of the structure to survive various ice encounters; and to measure hull temperature in order to determine hull temperature gradients. Table 5.1 summarizes the hull structure sensors as originally installed.

Table 5.1 Hull Structure Sensors

Measured Parameter	Derived Parameter	Type of Sensor	Range	Number of Channels
1. Hull Structure				
Structural Strains Starboard Bow	Ice Loads Impact Counts Pressures	Strain Gauge Ailtech Type SG 129	± 2000 Microstrains	139
Structural Strains Port Bow	Ice Loads Impact Counts Pressures	Strain Gauge Ailtech Type SG 129	± 2000 Microstrains	20
Structural Strains Field Ice Pressure Midship Hull	Ice Loads Impact Counts Field Ice Pressure	Strain Gauge Ailtech Type SG 129	± 2000 Microstrains	10
Hull Temperature Above Water Line	Temperature Gradient	Thermistors Fenwal Electric Type GB 32P2	- 20° to + 50°C	2
Hull Temperature Below Water Line	Temperature Gradient	Thermistors Fenwal Electric Type GB 32P2	-20° to + 50°C	2

5.2 Sensor Deployment

a) The strain gauges were originally deployed about the hull of the ship as directed by the results of a study to determine their optimum location for data gathering. Table 5.2 summarizes the original deployment plan. The bow gauges provided data to enable the assessment of the behavior of the structure during ice encounters, the midship gauges were used primarily to measure field pressure effect.

Table 5.2: Hull Structure S/G Deployment (Original Installation)

	Stbd Bow (See Fig. 5.1)	Port Bow (See Fig. 5.2)	Midships (See Fig. 5.3)
Main Frames	90	10	5
Web Frames	4	0	0
Stringers	4	0	0
Inner Shell	4	0	0
Outer Shell	38	10	5

The gauge deployment plan was modified in 1981 to include a third group of gauges on the starboard bow (see Fig. 5.4). Also in 1981 four gauges were added to the hull girders (see Fig. 5.5) to measure strains produced by the flexing of the ship.

b) Four thermistors mounted forward on the shell plating and along stringer No. 6 (see Fig. 5.6) were used to derive the temperature gradient through the hull above the water line.

5.3 Description of Sensors and Sensor Circuits

a) Strain Gauges (see Fig. 5.7) Ailtech type SG-129 strain gauges were installed in all locations. They were welded to the ship's structure and then covered with the same coating as is used to protect the ballast tanks. Vinyl insulation was used for the strain gauge leads. Most of the gauges were located in the ballast tanks and thus must function under water. The gauges were installed on four separate occasions: when the ship was built, during repairs to the bow in 1978 and as required during retrofits in Hamburg in 1980 and in Antwerp in 1981.

Each strain gauge channel consists of the S/G, an amplifier (signal conditioning) card (see Figure 5.8) and if necessary, an interference filter. The signal conditioning card and filter are located in the appropriate junction box.

Two outputs are available from each amplifier card; the REAL representing actual strain currently on the gauge; and the PEAK representing the maximum positive strain reached during the previous sampling period.

The low-pass filter cards are used when necessary to suppress specific interference frequencies. Each filter card provides two corner frequencies; 25Hz for use with sampling rates of 100 samples/sec., and 125Hz for use with sampling rates of 500 or 1000 samples/sec. The filter cards do not offer a peak detection feature, selecting the PEAK output from a filtered channel in fact selects the 125Hz corner frequency.

b) Thermistors Fenwall Electric thermistors are installed. Each thermistor is paired with a 10K resistor on the amplifier card to form a voltage divider.

5.4 Maintenance Experience

5.4.1 Strain Gauges:

The failure rate of the strain gauge channels was excessive. Effectively, in terms of total number of gauges, the complete array failed and was renewed during the three and a half year operating period. Because of this abnormally high rate of attrition, the experience of the strain gauges is reported here in depth. The cause of the abnormally high rate stemmed from both the circuit design (i.e., auto zero circuitry, cascade effect) the component selection (i.e., strain gauges in a configuration not recommended by the manufacturer for underwater locations) and from apparent damage during installation. In order to maintain a sufficient number of channels operational for reasonable data gathering faulty gauges were replaced when possible, circuits were modified and trouble shooting procedures were carried out daily. In spite of this enhanced maintenance the full strain gauge array was never fully operational at any one time. Researchers analysing the data had to modify the plan of acquisition to accommodate the actual number of channels operating at any given time.

a) Failure Rate Experienced: (Table 5.3)

A gauge is considered to have failed when it is no longer possible to calibrate the channel using the balance potentiometer on the amplifier card (strain gauge drift) or when the sensor displays an open circuit failure.

The strain gauges were installed on four occasions as follows:

Mid 1978 - when the ship was built

Mid 1979 - during repair of ice damage

Mid 1980 - during retrofit in Hamburg

Mid 1981 - during retrofit in Antwerp

A history of the starboard bow gauges has been tabulated to demonstrate the failure rate. These statistics reflect only failed gauges, they do not reflect S/G channels not functioning due to the circuit problems (auto-zero and cascade effect) described in paragraph 5.4.1 (b). The percent failures are shown for three sets of gauges: those originally installed, those installed in Hamburg and those installed in Antwerp. Each group is broken down by starboard bow section and divided between plate and frame installations.

ORIGINAL GAUGES INSTALLED MID 1978

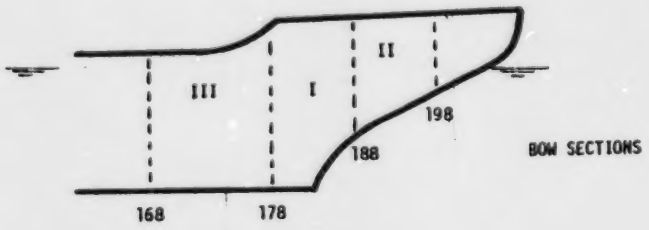
DATE TESTED (TIME INSTALLED YR.)	PLATES % FAILED		FRAMES % FAILED	
	SEC. I	SEC. II	SEC. I	SEC. II
Mid 79 (1)	30	69	37	32
" 80 (2)	79	85	37	32
" 81 (3)	96	92	79	76
End 81 (3½)	96	92	84	80

HAMBURG GAUGES INSTALLED MID 1980

DATE TESTED (TIME INSTALLED YR.)	PLATES % FAILED		FRAMES % FAILED	
	SEC. I	SEC. II	SEC. I	SEC. II
Mid 81 (1)	78	64	43	50
End 81 (1½)	83	64	43	57

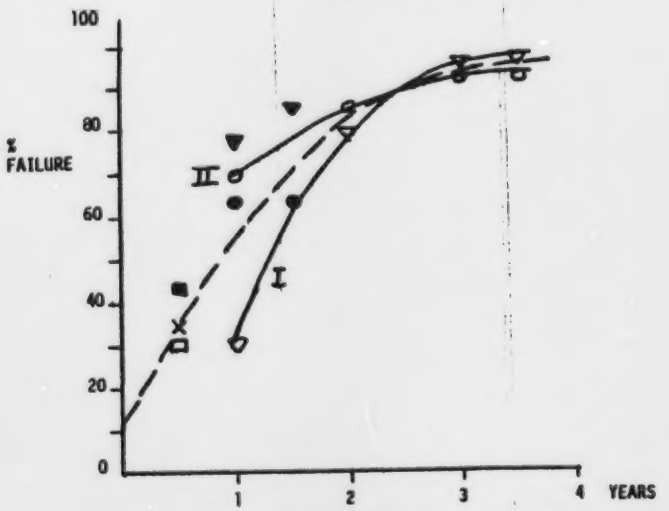
ANTWERP GAUGES INSTALLED MID 1981

DATE TESTED (TIME INSTALLED YR.)	PLATES % FAILED			FRAMES % FAILED		
	SEC. I	SEC. II	SEC. III	SEC. I	SEC. II	SEC. III
End 81 (½)	30	43	33	11	33	15



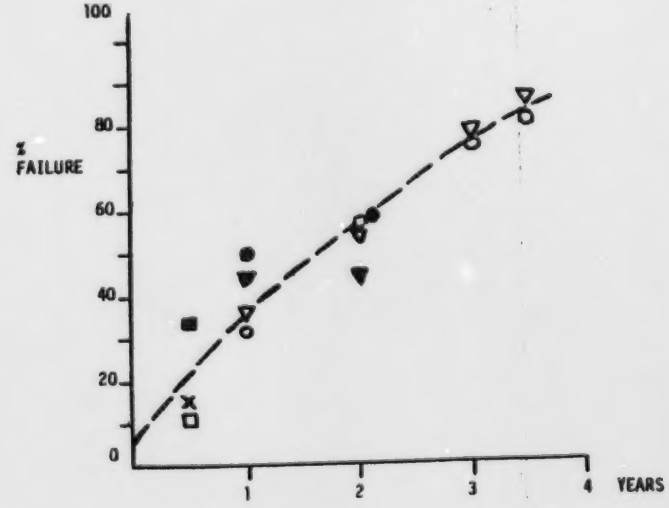
BOW SECTIONS

SUMMARY OF PLATE S/G FAILURES



▽ I ORIGINAL
○ II
▼ I HAMBURG
● II
□ I ANTWERP
■ II
XIII

SUMMARY OF FRAME S/G FAILURES



▽ I ORIGINAL
○ II
▼ I HAMBURG
● II
□ I ANTWERP
■ II
XIII

TABLE 5.3 STRAIN GAUGE FAILURE RATE

The cause of strain gauge failure falls into three categories: installation, local plate yield, water seepage.

i) Installation: Tests conducted immediately after installation, before any sea trials verified an attrition rate due to installation handling. For the original gauges and for those installed at Antwerp installation failures appear to account for 10 to 15 percent. For gauges installed at Hamburg this rate raises to 35 or 40 percent. Shipyard welding techniques may account for this variance.

ii) Local Plate Yield: The same type of sensors are installed on both plates and frames, furthermore they are installed by the same people, therefore the higher failure rate among plate sensors remains to be explained. It is possible that local plate yield causes permanent strains which exceed the balancing capability of the amplifier potentiometer. Corroboration for this view is found in the fact that failure rates along the waterline, the areas subjected to the most severe ice impacts are higher than the norm for a given section.

iii) Water Seepage: Recalibration of strain gauges' channels became necessary on a daily basis. Best evidence (see Appendix A) suggests that water seepage through the vinyl insulation of the strain gauge cables set up a variety of electrical anomalies which resulted in excessive strain gauge drift. Two actions were taken to try to alleviate this problem. In 1981 nine amplifier cards were fitted with extended range balance potentiometers, one failed within six months, Also in 1981 eight strain gauges with a polyurethane insulation were installed. One of those was damaged during installation but the remaining seven were functioning satisfactorily after six months.

b) Strain Gauge Circuit Maintenance:

In addition to the problems caused by failure of the strain gauges themselves, two design features of the system added to the maintenance time required to ensure reliable data gathering.

i) Auto Zero Circuitry: Originally an auto-zero circuit was included on each amplifier card to compensate for amplifier drift. The zeroing was achieved by removing the +10 volt supply from the strain gauge and adjusting the +5 volt reference level to the amplifier to produce a +5 volt output (the equivalent of 0 strain). The auto-zero circuit was later modified so that the +10 volts remained connected to the strain gauge during the auto-zero cycle. This modification was necessary because removing the +10 volt supply from one card caused erroneous signals to be sent from other amplifier cards in the same bin of the junction box. Issuing an auto-zero command then caused the circuit to register 0 strain regardless of the strain affecting the strain gauge. The computer program was set to give auto-zero commands every minute.

This operation was not compatible with the data collection routines and the auto-zero was switched off at the computer interface during most of the trials. The reference voltage to the amplifiers is reset from the "pre-set auto-zero" push button on the master cards. This action must be taken whenever power is removed from the cards.

ii) Cascade Effect: At the end of the 1980 season a "cascade" effect whereby one faulty strain gauge or amplifier can affect all 16 channels governed by a single master card was identified as a weak point of the system design. This cascade effect not only prevents immediate identification of the faulty channel but also jeopardizes the good health of the operating channels as successive replacement of each amplifier card in a bin with a known good amplifier card was frequently the only method of tracing the fault. Since the edge connectors of the cards were themselves a common source of faults, unnecessary removal and replacement risked damage to a good card or the introduction of contaminants into the connector. It must be noted however that card removal sometimes dislodged surface corrosion and cured the fault.

5.4.2 Thermistors:

All thermistors failed during the 1979 season. They were replaced during the 1980 retrofit in Hamburg but no useful data was ever available from these units. Repair of the thermistor array was not considered to be critical because a separate investigation was underway aboard the ship to determine heat flow through the hull.

5.5 Commentary and Recommendations

a) Strain Gauges

i) Sensor Selection: The Ailtech SG129 is not suitable for under water installation. Water can enter the cable through cracks caused by leeching of the polymers, through pin-holes formed in the vinyl during extrusion and through mechanical damage during installation.

Alternative - the use of sensors with polyurethane sheathed cable or vinyl cables oversheathed with a water proofed jacket is recommended. To further protect against moisture the strain gauge cable junction should be potted (see Fig. 5.9).

ii) Installation: Weldable strain gauges are usually installed using low energy capacitive discharge spot welding equipment.

Alternative - Bondable gauges which are installed using epoxy compounds may be subject to less rough treatment than gauges requiring welding. In light of the high installation failure rate of the MV Arctic bondable gauges should be considered for future installations.

b) Amplifier Cards

The auto-zero circuits should be redesigned so that it performs its intended purpose without interfering with system operation. Amplifier cards should also include:

- transducer failure detection
- filtering circuits that would not diminish system flexibility (i.e., selection of "real" and "peak" signals
- extended balance potentiometers
- isolation circuits so that failed sensors do not affect other channels and to permit cards to be replaced with power on without affecting other channels

c) Thermistors

The thermistor failures have not been reported on in any detail. This array had a low priority with both operators of the system and with those maintaining it. There is however no record of special shielding which is frequently required for a grounded installation such as thermistor sensors. Any new installation should review experience with working installations using the sensor selected.

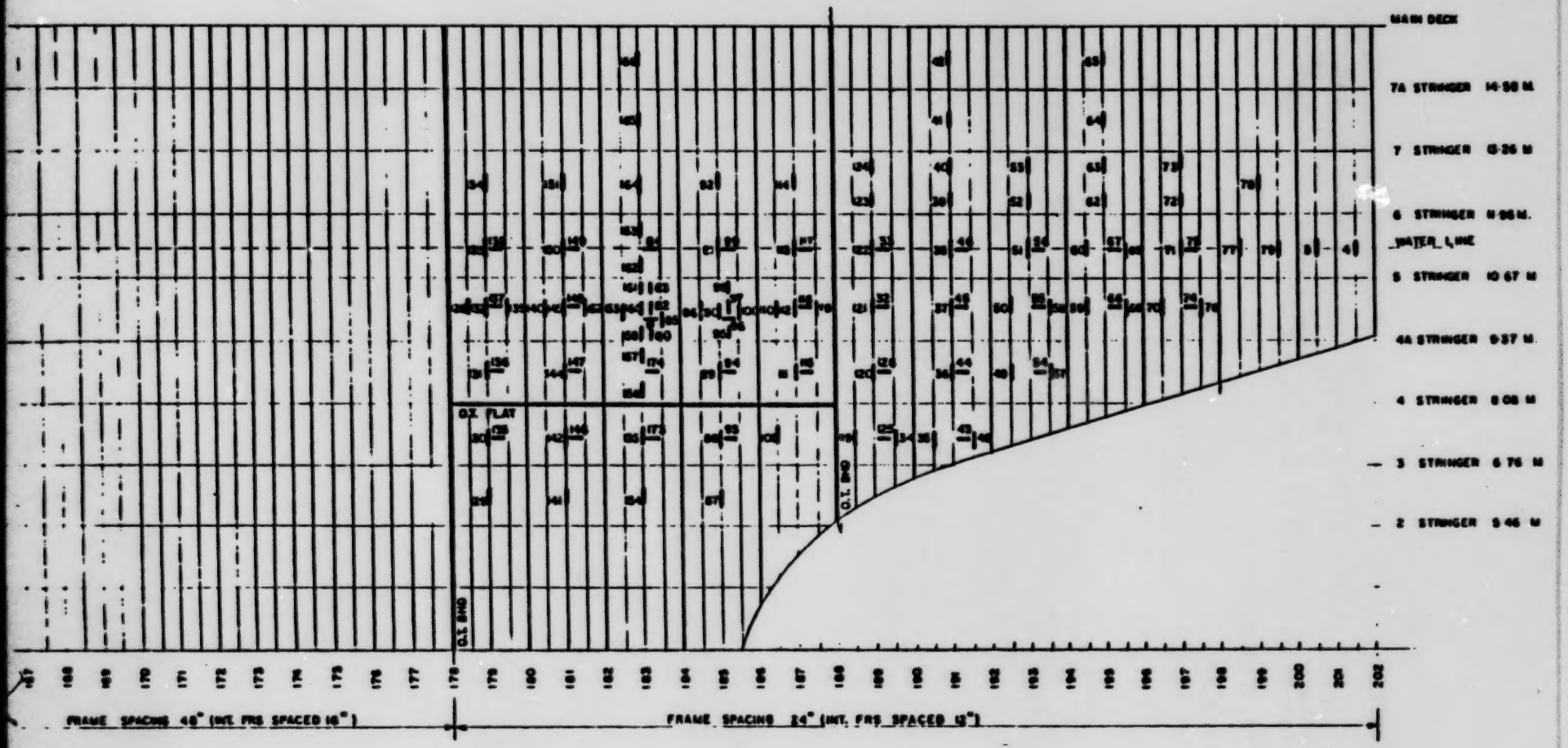


FIGURE 5.1 STARBOARD STRAIN GAUGES - ORIGINAL INSTALLATION

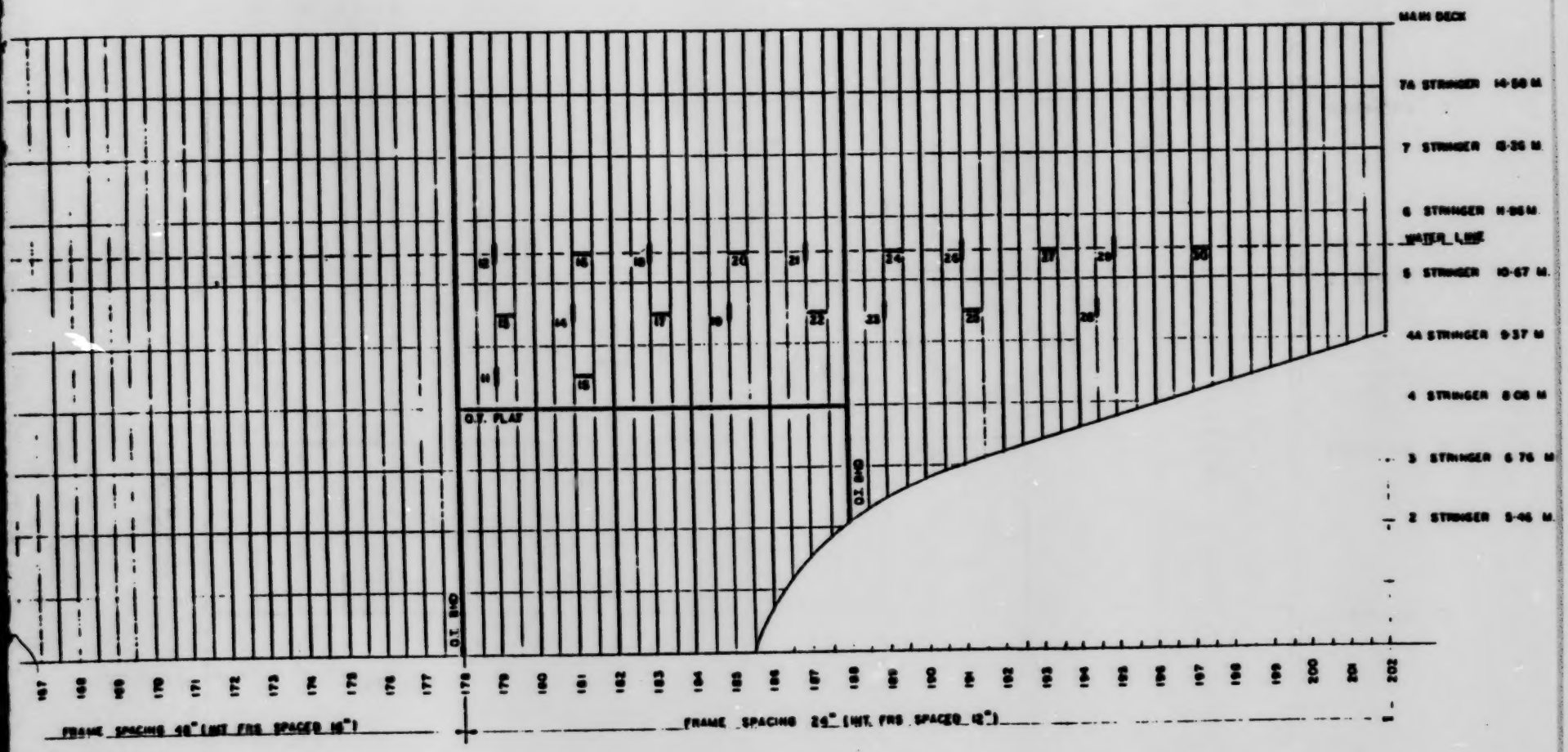


FIGURE 5.2 STRAIN GAUGES - ORIGINAL INSTALLATION (PORT)

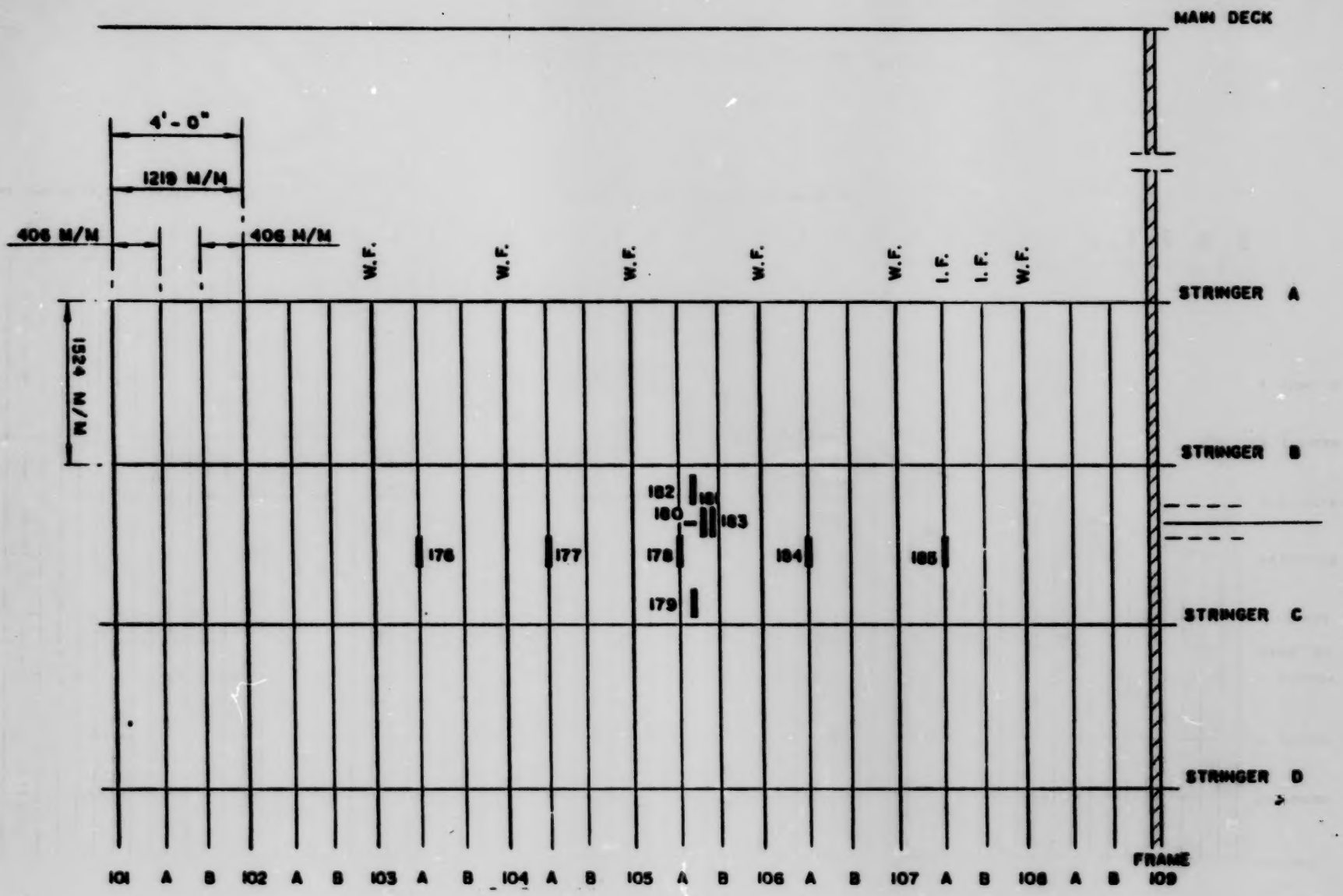


FIGURE 5.3 MIDSHIP STRAIN GAUGES - ORIGINAL INSTALLATION

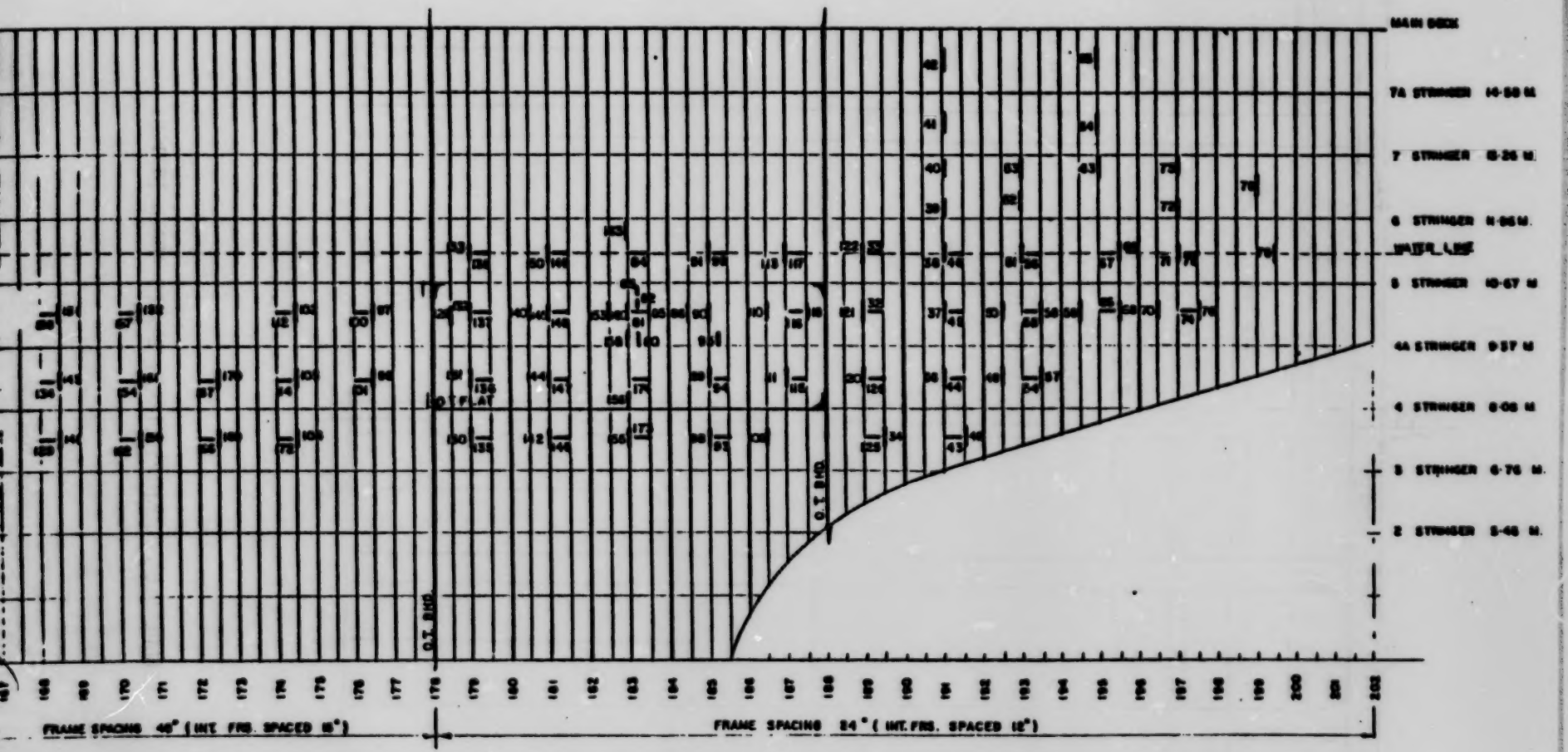

MAIN DECK
7A STRINGER 14·58 M.
7 STRINGER 13·26 M.
6 STRINGER 11·86 M.
WATER LINE
5 STRINGER 10·67 M.
4A STRINGER 9·57 M.
4 STRINGER 8·08 M.
3 STRINGER 6·76 M.
2 STRINGER 5·46 M.
O.T. FLAT
O.T. END
FRAME SPACING 48" (INT. FRS. SPACED 16")
FRAME SPACING 24" (INT. FRS. SPACED 12")

TABLE 5.4 STARBOARD STRAIN GAUGES - 1981 INSTALLATION

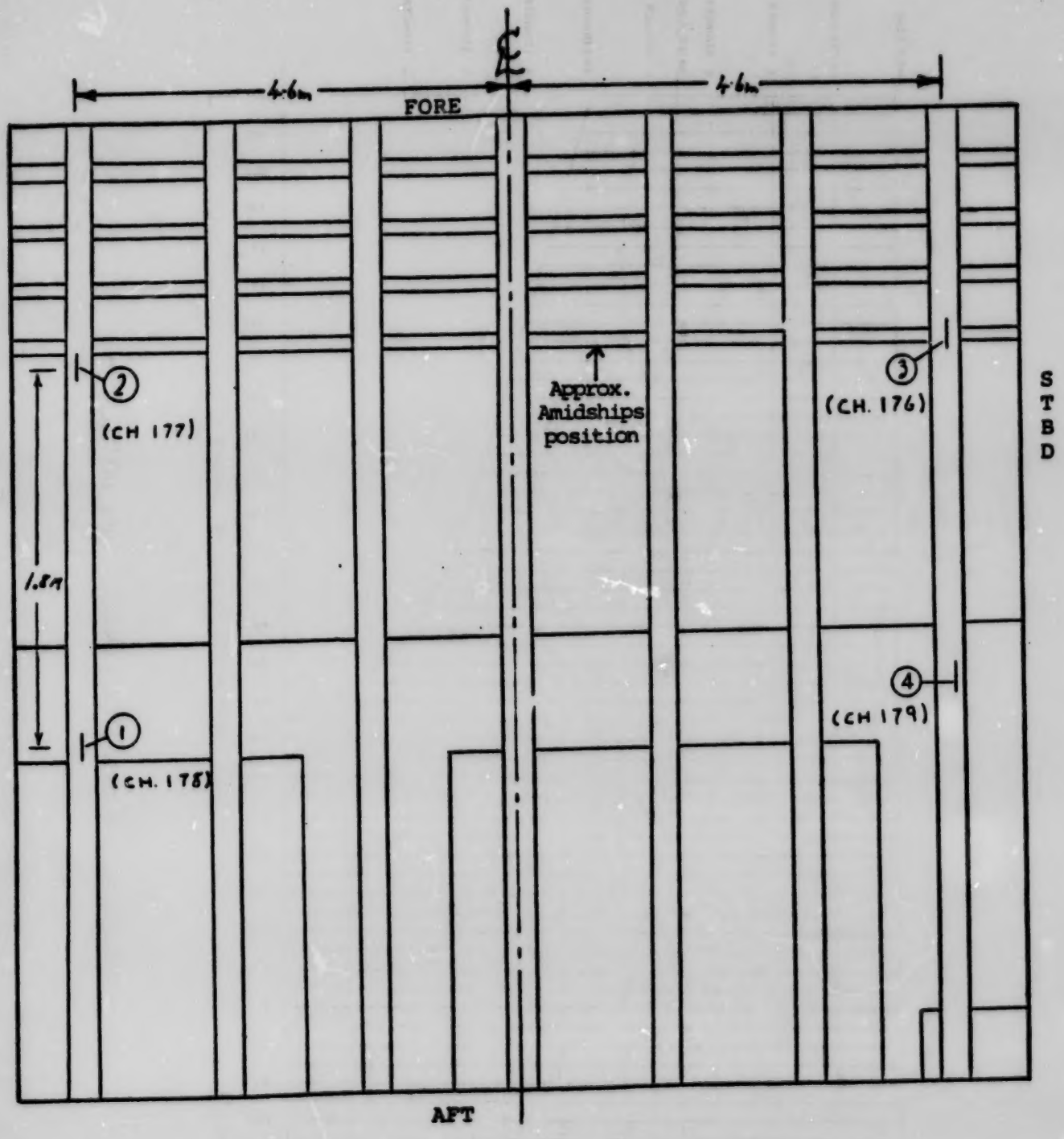


FIGURE 5.5 MIDSHIPS STRAIN GAUGES ADDED IN 1981

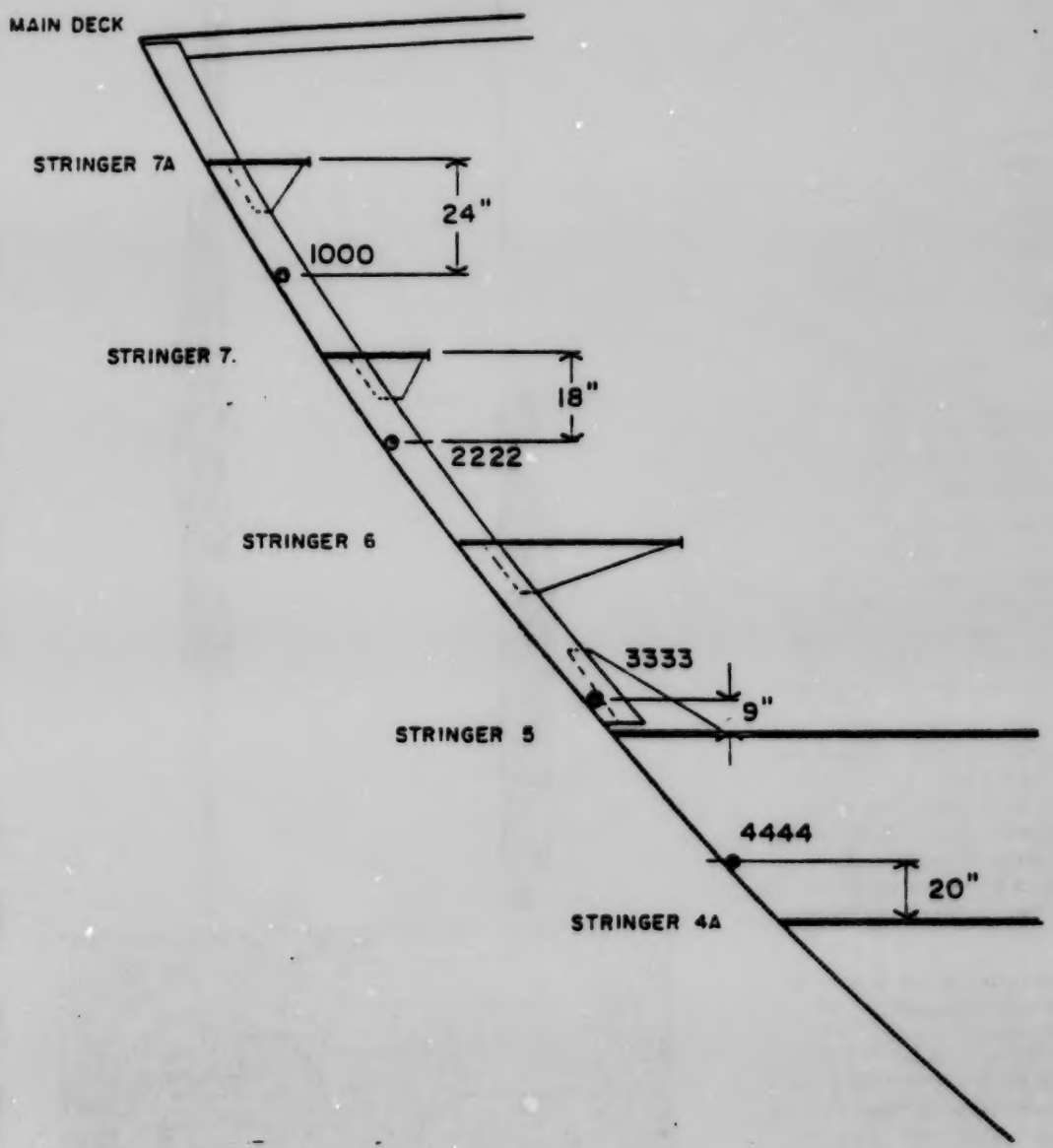


FIGURE 5.6 THERMISTOR ARRAY

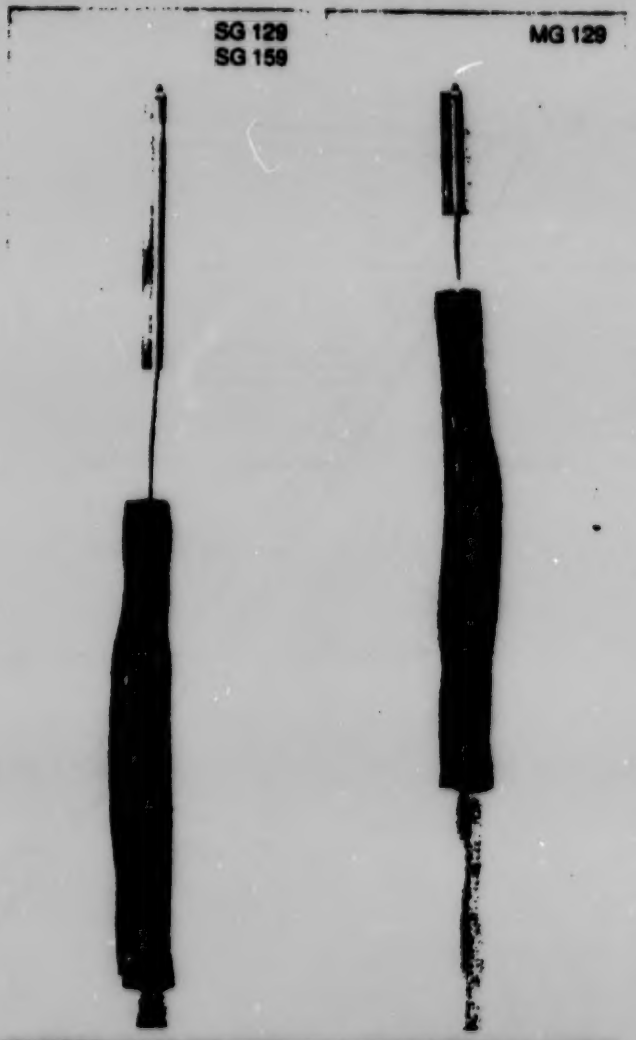
AILTECH
630 EAST WALNUT DRIVE • CITY OF INDUSTRY CA 91748
TELEPHONE (213) 965-4911 • TWX 910-584-1811

Weldable Strain Gages

SG 129, MG 129, SG 159 Series

120 and 350 OHM Quarter Bridge

For Static and Dynamic Measurements from −50° to 180°F.



FEATURES

- FLEXLEAD STRAIN GAGE
- WATERPROOF
- 0 TO 180°F STATIC OR DYNAMIC
- SELF TEMPERATURE COMPENSATED
- NICKEL-CHROME ALLOY
- 120 AND 350 OHM RESISTANCE
- ALL WELDED CONSTRUCTION
- INTEGRAL CABLE
- NO ADHESIVES REQUIRED
- SIMPLE RAPID INSTALLATION

DESCRIPTION

AILTECH Sealed Strain Gages are quickly installed in the field, providing immediate, reliable strain data at the lowest overall cost by eliminating hours of tedious preparation, installation and gage protection procedures.

AILTECH Weldable Strain Gages are available with 120 and 350 ohm, quarter bridge, nickel-chrome filaments, and are suitable for static and dynamic measurements from 0 to +180°F. They provide minimum apparent strains and are self-temperature compensated for your material. Quarter bridge gages are normally used from 0 to 180°F. Half bridge configurations provide more precise compensation in lower temperature spans.

The 350 ohm filament permits higher excitation voltages and reduces errors associated with long leads.
This flexlead strain gage provides the answer to the classic problem of "in the field" strain gage installation. They can be easily installed in any weather — even for submersible applications. Typical applications are for measuring strains on board ships, reinforcing steel, tunnels, buildings, and during pile driving.

Every Ailtech Strain Gage is pre-tested at the factory to its maximum operating temperature to assure proper operation in its intended application.

Ailtech Weldable Strain Gages are easily installed using low energy capacitive discharge spot welding equipment. A series of spot welds quickly makes the gage an integral part of the test structure, assuring complete strain transmission.

FIGURE 5.7 AILTECH STRAIN GAUGE (SHEET 1)

ELECTRICAL SPECIFICATIONS

Strain Gage Resistance

Model:	SG 129	SG 159	MG 129
Resistance:	120 ohms ± 1*	350 ohms ± 10	120 ohms ± 5

*When compensated for materials with thermal coefficient of expansion between ± 6.6 ohms and 10.5 ppm/°F. ± 3 ohms when compensated for other expansion ranges.

Integral Lead Wire Resistance
.016 ohms / ft. at 75°F.

Excitation Current
Continuous: 50 ma maximum
Pulsed: To 300 ma depending on operating temperature and test structure.

Insulation Resistance
Greater than 1000 Megohms at 50 vdc measured at 75°F.

PERFORMANCE SPECIFICATIONS

Gage Factor

SG 129 and SG 159	1.9 Nominal
MG 129	1.7 Nominal

Actual Gage Factor is reported for each lot.
Gage factor for all gages within a particular lot is within ± 3%

Rated Strain Level:
± 20,000 microinches per inch

Fatigue Life:
Exceeds 10^6 cycles at ± 1,000 microinches per inch

Transverse Sensitivity:
Negligible (Line weld between strain tube and mounting flange)

ENVIRONMENTAL SPECIFICATIONS

Operable Temperature Range
Static and dynamic measurements −50 to 180°F.

Compensated Temperature Range
Gages are individually Temperature compensated

Designation	Temperature Range
−11	0 to 180°F.
−09	Special Range (Specify on order)

Caution: If the temperature of the strain gage exceeds 180°F. the vinyl insulated cable may be damaged.

Humidity: 100% at 180°F; 100 PSI at 80°F.

Apparent Strain vs. Temperature
Each gage is adjusted to an optimum unmounted terminal slope value, depending upon the material on which the gage is to be mounted, within a strain tolerance of 50 microinches per inch. When the gage is installed, the mounting terminal slope will be within a strain tolerance consisting of the summation of ± 75 microinches per inch and ± 3% of the unmounted terminal slope.

Gage Factor Change with Temperature:
Gage Factor varies inversely with temperature approximately 1% per 100°F. over the compensated temperature range.

Additional Environments:
The strain gages have been subjected to the following environments and levels without deterioration of performance.

Linear Sinusoidal Vibration: 35g, 20 to 2000 cps
Static Acceleration: 50g
Shock: 100g half sine, 7 millisecond duration

MECHANICAL SPECIFICATIONS

Strain Gage Configurations:
Refer to dimensional outline drawings shown on front.

Electrical Connections:
Red — Active, Black — Dummy, White — Common

Strain Gage Center:
The strain gage center is at the center of the mounting flange.

Active Gage Length:
0.91" for SG 129, 0.61" for SG 159 and 0.21" for MG 129.

Strain Gage and Mounting Flange Material:
AISI Type 321 stainless steel. Intended for mounting on weldable ferrous and nonferrous materials.

Lead Wire:
Vinyl insulated AWG 22 gage shielded wire with vinyl insulation overall. Usable to 180°F and recommended for direct embedment in concrete. Very rugged cable.

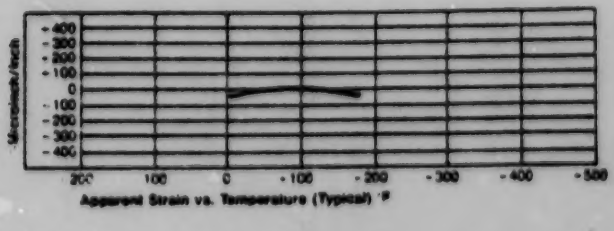
ORDERING INFORMATION

Detailed ordering information and available options are shown on a separate instruction sheet.

Standard Gages
Standard Gages are stocked in limited quantities for immediate shipment. These gages solve the majority of strain measurement problems encountered. They include ten feet of integral cable, and are compensated to match 1018 steel (6S) or 321 stainless steel (9S) over the temperature range of 0 to 180°F.

Custom Gages
Ordering of Custom Gages with other cable lengths, temperature ranges, options, compensations etc., requires a detailed build-up of the Custom model number.

Consult factory for further information or applications assistance.



Apparent Strain vs. Temperature (Typical) °F

FIGURE 5.7 AILTECH STRAIN GAUGE (SHEET 2)

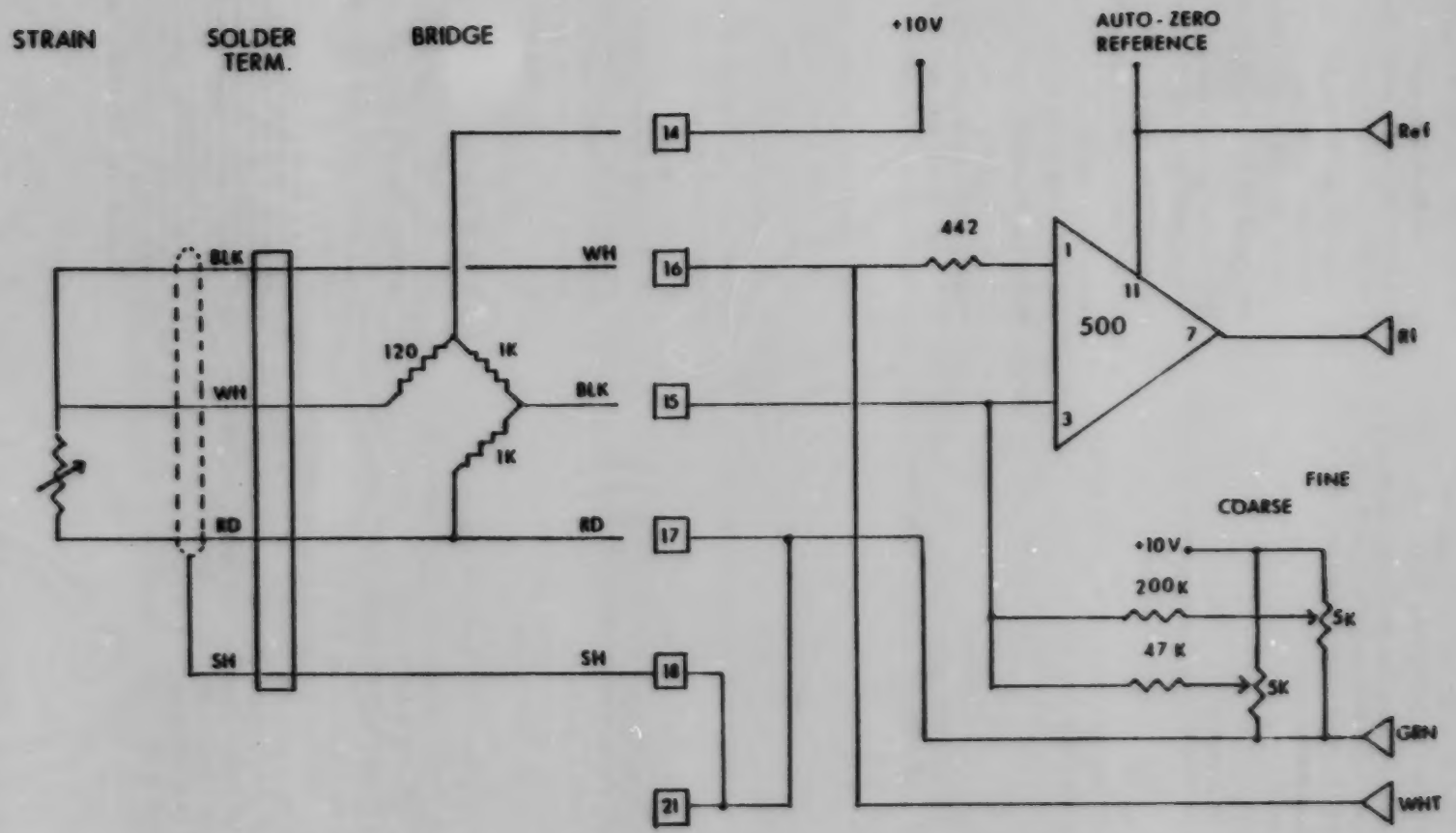


FIGURE 5.8 STRAIN GAUGE AND ASSOCIATED AMPLIER CARD

FIGURE 5.9 BONDED STRAIN GAUGE INSTALLATION
WITH POTTED CABLE CONNECTOR

6. PROPULSION SYSTEM SENSORS

6.1 Purpose

The performance of the main propulsion system was monitored and selected parameters were recorded in order to correlate the system response to ice encounter and to establish a relationship among power and thrust and ship's speed under various operating conditions.

6.2 Recorder Parameters

Provision is made for the measurement and recording of parameters relating directly to the performance of the propulsion system. The main parameters measured are:

Shaft Torque
Shaft Thrust
Shaft RPM

In addition, the following secondary parameters are measured:

Fuel rack setting
Engine RPM
Propeller command, response, and spindle torque

Table 6.1: Propulsion System Instrumentation

Measured Parameter	Derived Parameter	Type of Sensor	Range	No. of Channels
Shaft Torque	Shaft Horsepower	S/G Bridge & Telemetry Torque Meter	0 - 0.8 Mega-Newton-metres	1
Shaft Thrust	Propeller Thrust	Rank Thrust Meter Type-RCIK-3	± 120 MegaPons	1
Shaft RPM	Shaft Horsepower	1) Ships Shaft Tachometer	RPM 0 - 200	1
		2) Search coil mounted above shaft to detect passing of magnet on shaft	RPM 60 - 200	2
Fuel Rack Position	Fuel Consumption Brake Horsepower	Follow-up Potentiometer	0 - 100% of full travel	1
Engine RPM	Brake Horsepower	Ship Engine Instrumentation	RPM 0 - 600	1
Propeller Pitch Response	Pitch Change Resistance	Follow-up Potentiometer	- 22° Astern + 22° Ahead	1
Propeller Pitch OD Box Differential Pressure	Propeller Spindle Torque	Pressure Transducer SELABS Type SE21/V	0 - 14 Mega-Pascal	1
Propeller Pitch Command	-	Follow-up Potentiometer	+ 10 Ahead - 10 Astern	1

6.3 Description of Sensors and Maintenance Experience

6.3.1 General

The status of the ship's propulsion was monitored either by taking readings from marine equipment (RPM, thrust) or through pick-up sensors connected mechanically to the machinery control linkages (propeller pitch, fuel rack). The shaft torque meter was custom built and designed for the application. Each sensor was connected to a signal conditioning amplifier. These amplifiers have the same basic design as those used for the strain gauges although the auto-zero was disconnected and other changes made to suit the gain and balance requirements of specific sensors.

6.3.2 The Shaft Torque

The shaft torque is derived from voltages supplied by a torque meter (See Appendix B). Strain gauges are located on the shaft to sense torque, their output is processed and transmitted to the non-rotating receiver instrumentation in an adjacent cabinet and then to the signal conditioning amplifier.

Maintenance: This unit could not be made to function correctly during 1979. Problems encountered ranged from apparent extreme sensitivity in the circuit and damaged leads to insensitivity in the readings obtained. Trouble shooting was not yet completed when the torquemeter and all its connections were removed during repairs in Hamburg (May 1980). During the 1980 Saguenay Trials a Torquemeter supplied by the National Research Council was used in an attempt to calibrate the MV Arctic's torquemeter.

The experience gained in calibration techniques during the Saguenay Trials permitted appropriate calibration procedures to be established and this unit was made to function satisfactority for the balance of the 1980 and 1981 seasons. A failure of the torquemeter channel reported in 1981 was due to damaged leads on the shaft mounted strain gauge bridge. They had apparently caught on some obstruction. After repair the instrument was again deemed operational.

6.3.3 Shaft Thrust

Monitored by a Renk thrust meter which provides a voltage output between $\pm$ 10 Volts proportional to the thrust. The associated amplifier card has a ref. voltage of + 5 V and a gain of 0.5 to convert the $\pm$ 10V output of the thrust meter to a 0V to +10V amplifier output. The main gearbox, also supplied by Renk, was instrumented and calibrated during assembly by the manufacturer.

Maintenance: Testing in 1979 revealed faulty interconnected cables to the Renk gearbox that could not be repaired until the end of the 1979 season. Once the system was repaired it functioned well during the various trials in 1980/1981.

6.3.4 Shaft RPM

Shaft RPM was to be measured through taps on the ship's tachometer, however a defective chain drive on the ship's equipment prevented this output from being available. In the summer of 1980 a sensor was designed to measure RPM directly off the shaft. A search coil mounted above the shaft registers a pulse each time a magnet strapped to the shaft passes. The signal is amplified by the card in channel 209. By sampling this channel at a rate of "10 samples/sec peak" a pulse is recorded on tape every time the shaft makes one revolution. This technique worked but was inefficient in that it required significant manual calculations to arrive at an RPM measurement. The designers then added an analog circuit to the sensor. This circuit counts and stores the shaft rotational pulses and provides an analog ranging from 0 volts to +10 volts that is directly proportional to the shaft period. The circuit is such that shaft rpm's of less than 58.82 rpm will give false readings. This is not considered to be a problem since the shaft is normally operated faster than this rpm. The analog channels are located in channel slots 210 and 211.

Maintenance: The shaft rpm as redesigned functioned well until the end of 1981. Its failure at this time remains unresolved. Table 6.2 gives an operating history of the propulsion machinery sensors.

6.3.5 Fuel Flow

Derived from the voltage output of a potentiometer attached to the fuel rack setting mechanism.

Maintenance: After initial calibration no problems were encountered with this sensor. One recalibration was required to permit metric readings of fuel consumption.

6.3.6 Engine RPM

Engine RPM is recorded through taps connected directly to the ship's instrumentation.

Maintenance: The original unit was calibrated and functioned appropriately. Concern of possible interference with the ship's alarm system was expressed by the ship's operators and the taps were removed from the ship's instrumentation. The owners undertook to install a new system to provide data - this had not been done by the end of the 1981 season.

6.3.7 Propeller Command and Response

Monitored through follow-up potentiometers. The command potentiometer is connected to the pitch control mechanism on the bridge; the response potentiometer is connected to the pitch response linkage on the oil distribution box in the engine room.

Maintenance: No major problems were encountered with the command sensor although it could not be used during some trials due to telemetry equipment failure. The response sensor had to be reconnected and recalibrated after repairs to the ship in Hamburg, May 1980.

6.3.8 The Propeller Spindle Torque

Derived from a measurement of the hydraulic pressure on the actuating system combined with the blade pitch position. We must note that there is disagreement among researchers analysing the data as to whether or not propeller spindle torque can actually be derived from these data. A differential pressure transducer providing an output of ± 1 V is fitted on the oil distribution box to measure hydraulic pressure. The conditioning amplifier uses a + 5 V ref. and a gain of 5 to give a 0 V to +10 V output over the range.

Maintenance: Initially, although the transducer response seemed reasonable, the unit could not be calibrated. In June of 1981 it was found that the transducer connection had been piped into the wrong location on the oil distribution box. When the transducer was fitted correctly and its signal conditioning amplifier replaced with one of higher gain the unit functioned satisfactorily.

6.4 Commentary and Recommentations

Reliable information from the main propulsion sensors, shaft torque, thrust and RPM is of major significance to the usefulness of the data received from most of the other sensors in the acquisition system. For the MV Arctic none of these sensors functioned until the 1980 season and it was not until the 1981 season that all three sensors were on line.

Among the secondary sensors, fuel rack, engine rpm and propeller command and response and control only the fuel rack and the propeller command and response were relatively trouble free.

In brief, the situation was as follows:

Shaft Torque - a lack of understanding of the sensor circuit prevented appropriate calibration procedures from being defined until late 1980. Additionally the circuit cabling was physically damaged twice.

Shaft Thrust - faulty cable interconnect during installation.

Shaft RPM - Ship's equipment faulty. Redesigned circuit provided reduced level of information, e.g. rpm range 60 to 200 rpm only.

Fuel Rack - satisfactory.

Engine RPM - Removed because of suspected interference with ship's alarm system.

Propeller Command/Response - satisfactory.

Propeller Control - Wrongly connected during installation.

In order to forestall similar problems in future installations, system designers should:

1. Develop, test and document calibration procedures for all sensor circuits prior to installation.

2. Be sensitive to the possibility of the data acquisition component causing interference to the host unit (e.g. engine rpm). If there is any doubt develop alternative means of acquiring the data.

3. Provide for installation inspection.

Furthermore, for the critical parameters of shaft torque, thrust and rpm, duplication of sensors should be considered.

Year		1979	1980	1981
Voyage		1 2 3 4 5 6 7	1 2 4 5 6 T1 T2 *	1 2 6 7 8 9 10 T1 T2 **
Measured Parameter	Channel No.			
Shaft Thrust	198		X X X X X X	X X X X X X X X
Shaft Torque	208	X X X	X X X X X X	X X X X X X X X
Shaft RPM	242		/ / X	
Shaft RPM	211			X X X X X X X X
Shaft RPM	209		/	X X X X X X
Engine RPM	241	/		
Propeller Pitch	201	/ X X X X	X X X X X X	X X X X X X X X
Ship Speed	236	/ X	X X	X X X X X X X X
Wind Speed	233	X X X	X X X X X X	X X X X X X X X
Wind Direct.	234	/ X X X	X X X X X X	X X X X X X X X

* T1 - Saguenay River Trials
T2 - Baffin Island Trials

** T1 - Lake Melville Trials
T2 - Admiralty Inlet Trials

X Channel fully operational
/ Channel partially operational

TABLE 6.2 OPERATING HISTORY OF PROPULSION SENSORS

7. SHIP PERFORMANCE SENSORS

7.1 Purpose

The magnitude of various ship's motions (e.g. speed, pitch, roll) was monitored and recorded providing real time data to assist in analysing performance under various ice transiting conditions. The rudder angle and torque were also monitored as were the fore and aft draft of the ship.

7.2 Recorded Parameters

Provision was made for the measurement and recording of the following performance parameters:

- Acceleration (fore and aft)
- Rudder command and response
- Rudder stock torque
- Ship's speed
- Ship's head
- Pitch and roll
- Draft (fore and aft)

Table 7.1 summarizes the ship performance instrumentation.

Table 7.1: Ship Performance Instrumentation

Measured Parameter	Derived Parameter	Type of Sensor	Range	Number of Channels.
Accelerations Heave, Surge, Sway - Fwd	Ship Motions Ice Forces	Accelerometers Entran Devices Inc. EGC-240-107	± 10G	3
Accelerations Heave, Surge, Sway - Aft	Ship Motions Ice Forces	Accelerometers. Entran Devices Inc. EGC-240-107	± 10G	3
Rudder Angle Command/Response	Rudder Change	Follow-up Potentiometer	37.5^{0} Port 37.5^{0} Stbd	2
Steering Gear Differential Pressure	Rudder Stock Torque	Pressure Transducer SELABS Type SE 21/7	0 - 35 Mega-Pascal	1
Ship's Speed	Resistance	Doppler Log-Sperry Type SRD-301 12 Bit Digital Number	0 - 50 Knots	1
Ship's Head	Turning Rate	Gyro Compass Type 37 Sine & Cosine of Heading	$0 - 360^{0}$	2
Pitch	Ship Motions	Vertical Gyro - Humphry Inc.* Model VH02-0127-1 Pitch Axis	0 - 40 Degrees Head & Stern	1
Roll	Ship Motions	Vertical Gyro - Humphry Inc.* Model VH02-0127-1 Roll Axis	0 - 40 Degrees Port & Starboard	1
Draught (Fwd)	Displacement Wetted Surface	Manual Operation Decade Switch	7-12 Metres 1/2 Metre Steps	1
Draught (Aft)	Displacement Wetted Surface	Manual Operation Decade Switch	7-12 Metres 1/2 metre Steps	1
Rudder Torque (1981)		S/G	± 1136 KNm	1

* These units were aircraft type Minneapolis Honeywell units rebuilt by Hymphry Inc.

7.3 Description of Instrumentation and Maintenance Experience

7.3.1 Acceleration

Two sensor units made up of three accelerometers each provide signals proportional to heave, surge and sway of ship at the sensor location. The sensors are located in the fore peak space and in the engine room aft. Each accelerometer has a different sensitivity and is matched with a signal conditioning amplifier to give outputs of 0V, +5V and +10V which correspond to accelerations of -2.5g, 0g and +2.5g respectively. Since those sensors are not located at the center of gravity of the ship, a derivation of the translational motion of the ship as a whole cannot be made.

Maintenance: Testing of the accelerometer channels revealed severe interference on the three units located in the aft engine compartment. Low pass filters were installed on the three aft units early in the 1980 season and on the three forepeak units during the summer of 1980. The filter cards have two outputs, one with a cut-off frequency of 1.2 Hz used for sampling rates of 10 samples/second, and one with a cut-off frequency of 12 Hz for use at higher sampling rates. The 1.2 Hz was designed to give a clear output of rigid-body accelerations affecting the ship while the 12 Hz output is available to give higher frequency details if required. These units were easily calibrated and functioned well for the balance of the trial period. One accelerometer required replacement during the early trials of 1981.

7.3.2 Rudder Command and Response

Monitored through follow-up potentiometers. The command potentiometer is connected to the wheel on the bridge; the response potentiometer is connected to the rudder stock in the steering flats.

Maintenance: Problems were encountered with the command sensor. It ceased to function when a set-screw on the wheel coupling became loose. Tightening the set-screw and recalibrating the sensor restored the channel for the 1980 season. The potentiometer had to be replaced at the start of the 1980 season. No problems were encountered with the rudder response channel.

7.3.3 Rudder Stock Torque:

In the initial design this parameter was to be derived from a measure of the hydraulic pressure on the rudder actuating system combined with a measure of the rudder angle position.

Maintenance: The output from the pressure transducer sensing the differential pressure between the two rudder hydraulic control rams seemed reasonable, however the data channel could not be calibrated. Attempts at resolving the calibration problem, which centered mainly around manipulating the formula used to derive the torque, were unsuccessful. In May 1981, a strain gauge array was mounted directly on the rudder stock. This data channel functioned well until the very end of the 1981 season when it failed. The cause of its failure has not been determined.

7.3.4 Ship's Speed

Monitored through an output from the ship's Doppler Speed Log. The digital output from the log is converted to an analog signal for use in the instrumentation system. The analog output is sent to a signal conditioning amplifier with a gain of 3.3 and a ref. voltage of 0V. The 0 to +10V output range of the amplifier, theoretically, corresponds to a speed range of 0 to 30 knots.

Maintenance: Throughout 1979 and 1980 the speed reading on the data channel was inaccurate. This fault was thought to be a problem with the Sperry Doppler Log and a great deal of time was spent by the Sperry people trying to trouble shoot the log. The fault was finally traced in October 1980 to a faulty capacitor on the 30V power supply. Subsequently the Doppler Log was modified to update its displayed output every 2.8 seconds rather than every 14 seconds as originally set. This change was to accommodate monitoring the rapid speed changes that occur during ramming operations. Two point eight seconds is the lowest setting available on the Log; there is concern that for some operating conditions a one second display would be more appropriate. No further problems were encountered with this channel.

7.3.5 Ship's Head

Monitored through a tap on the ship's No. 2 gyro compass. The unit is factory modified to include sine/cosine potentiometer which provides two output voltages proportional to the sine and cosine respectively of the compass heading. Both associated amplifier cards must be in place and working correctly for any data to be obtained.

Maintenance: No problems were encountered in the operation of this channel.

7.3.6 Pitch and Roll

Voltages proportional to the Pitch and Roll of the ship are taken from potentiometers connected to a vertical gyro located in the laboratory of the ship.

Maintenance: Pitch and Roll gyro gave erratic readings from both pitch and roll axis throughout 1979. This problem was finally resolved when the gyro bearings were cleaned and oiled. The sensitivity of the unit was found to be too low by a factor of 10 on the pitch and 20 on the roll, hence new signal conditioning amplifiers were installed. In 1980 the unit was deemed to be unserviceable. A new Minneapolis Honeywell vertical gyro was installed and after calibration the data channels functioned well for the balance of the trials.

7.3.7 The Draft Forward and Aft of the ship from which the displacement of the wetted surface is derived is input manually to the system through decade switches.

Maintenance: No problems were encountered with this channel.

7.4 Commentary and Recommendations

The sensors used for the ship's motion measurements were in the main reliable and functioned as they were designed to. There are however several areas of concern.

Ship's Speed: The troubles experienced with the Doppler Log rendered this source unreliable through the 1979/80 season. Subsequent analysis of the data collected revealed that the data was unreliable at low speeds and during backing-up operations. The low speed characteristics of the Log would appear to make this unit inappropriate for use as a ship's speed source for data acquisition systems.

Rudder Torque: The inability to calibrate this channel, even though the sensor circuit appeared to function appropriately, necessitated a redesign of the sensor in 1981.

Accelerometers: The necessity to use filter cards in these circuits eliminating the availability of "peak" readings.

Pitch and Roll: Component failure.

Although the Doppler Log had severe problems of its own, it also constitutes an example of a data circuit not functioning due to an interconnect problem. Similarly, the rudder torque problem underlines the necessity to develop, test and document calibration procedures for sensor prior to installation.

The use of filter cards to combat the interference experienced on the accelerometer circuits solved the interference problem but it diminished the operation of these circuits. The input to the filter card is taken from the "real" signal output on the amplifier card hence the "peak" signal output, stored between samples, is no longer available to the system. New cards should be designed so that the "peak" storage feature is retained when filtering is required.

8. AUXILIARY SENSORS

8.1 Purpose

The ship was fitted with a thruster/bubbler system. Auxiliary instrumentation was provided to monitor the operation of this system so that comparisons could be made of the ship's performance with and without the bubbler functioning.

8.2 Recorded Parameters

Provision was made to measure the air pressure of the bubbler system at the port and starboard compressors and to monitor the status of the control valve settings. Table 8.1 summarizes the Bubbler System Instrumentation.

Table 8.1: Bubbler System Instrumentation

Measured Parameter	Derived Parameter	Type of Sensor	Range	Number of Channels
Air Pressure Bubbler Compressor Starboard	Air Volume Flow	Pressure Transducer Entran EPS - 1032-50	0-35 Kilo-Pascal	1
Air Pressure Bubbler Compressor Port	Air Volume Flow	Pressure Transducer Entran EPS - 1032-50	0-35 Kilo-Pascal	1
Bubbler Valve Status	Bubbler Mode	Decoding Relays - from Modem of Valve Status	ON-OFF	3

8.3 Description of Instrumentation and Maintenance Experience

8.3.1 Air Pressure

Air pressure was measured in the primary manifold of each manifold of each compressor. Entran Model EPS-1032-50 pressure transducers were used together with an amplifier card providing a gain of 330 to give an output of 0V to+10V corresponding to pressure of 0 to 20 psi. A DC/DC voltage converter was used to provide the 6VDC exitation required for the pressure transducer (see Fig. 8.1).

Maintenance: Initially a pressure transducer was installed badly and subsequently broke. It was replaced. The instrumentation was checked from time to time by signal injection and was operational.

8.3.2 Bubbler Valve Status

Bubbler valve status was taken off mimic boards of the bubbler system. The voltage from the bubbler system was not appropriate to drive the instrumentation relays, hence relay drivers were added. Three valve positions were monitored; port bubblers, starboard bubblers, and thrusters - blow offs.

Maintenance: A transistor failed in the driver circuit and required replacement in 1980. The instrumentation was operational for most of the trial period.

8.4 Commentary and Recommendations

The data acquisition system was able to monitor the bubbler system during trials and on other occasions as appropriate. The availability of spare channels in the design of the data system for use with auxiliary systems as required by the ship's operators is an attractive feature of the MV Arctic installation and should be considered for any new installation. As recommended for other sensor groups, installation inspection must be allowed for to prevent sensors from being improperly attached to host equipment.

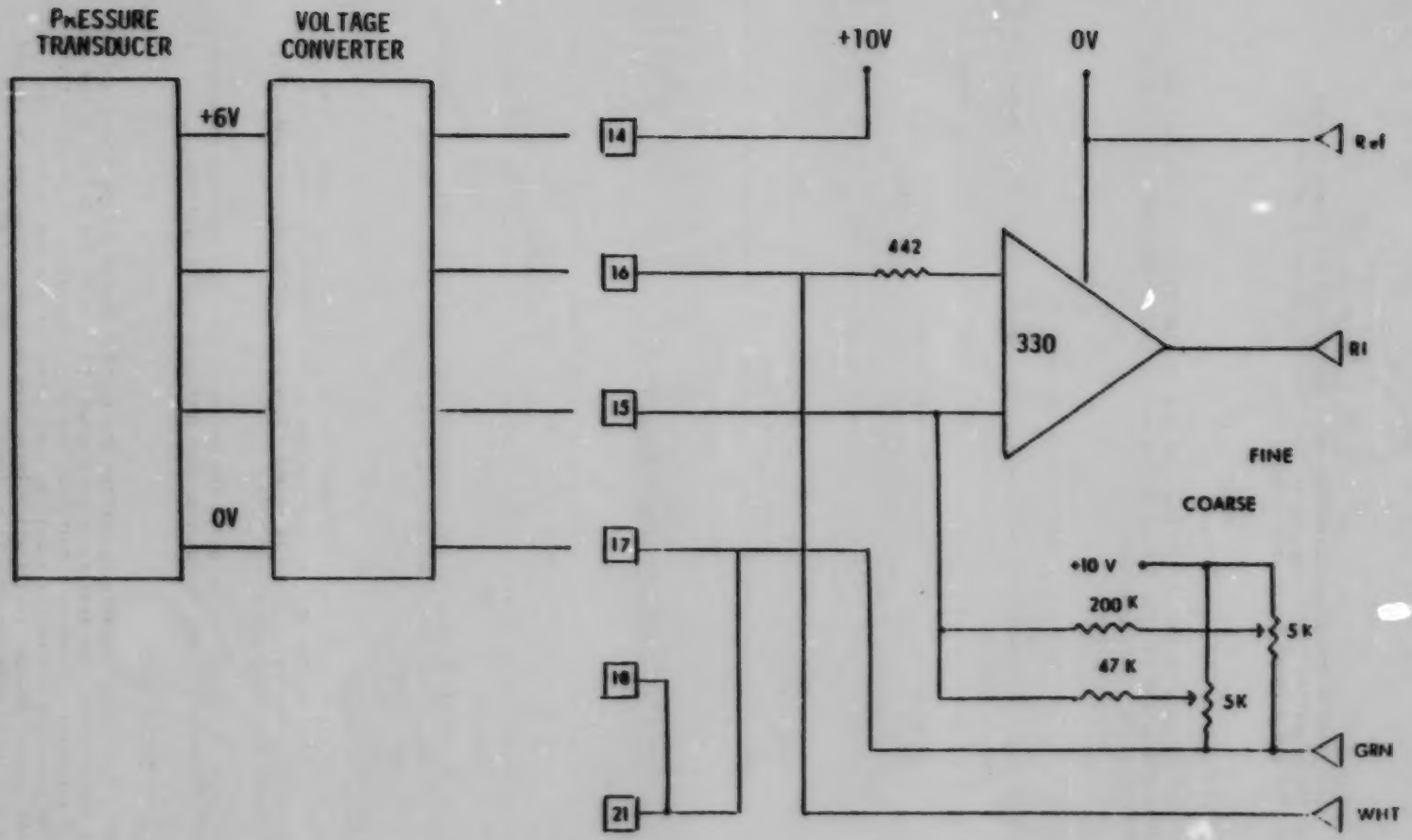


FIGURE 8.1 BUBBLER PRESSURE SENSOR

9. ENVIRONMENTAL PARAMETERS

9.1 Purpose

Prevailing environmental conditions are monitored in order to determine their effect on the other data gathered. Additionally, as one objective of the program is to provide an instructional base upon which the expertise of ice navigation and commercial ship operation in arctic waters may be further developed, the long term statistical data from this group of sensors is valuable.

9.2 Recorded Parameters

Slowly changing environmental parameters such as visibility in nautical miles, ice cover and cloud cover in tenths, air temperature in degrees Celsius, relative humidity in percentage, and barometric pressure in millibars are manually input to the system through decade swithes located on a console on the bridge. More rapidly changing parameters such as wind speed and direction are entered automatically through sensors on the output of the ship's anemometer and wind vane. In practice this data has been supplemented by a manual log of weather observations.

Table 9.1 summarizes the Environmental Instrumentation.

Table 9.1: Enviromental Parameters

Measured Parameter	Derived Parameter	Type of Sensor	Range	Number of Channels
Cloud Cover	-	Manually operated decade switch	0-10 tenths cover	1
Ice Cover	-	Manually operated decade switch	0-10 tenths cover	1
Barometric Pressure	-	Manually operated decade switch	0-100 Kilo-Pascals	3
Air Temperature	-	Manually operated Bourns Knobpot	0-100^{0}C	1
Relative Humidity	-	Manually operated Bourns Knobpot	0-100%	1
Wind Speed	Wind force and moment	Anemometer Tachometer-Meteorological Instrumentation	0-100 Knots	1
Wind Direction	Wind force and moment	Wind vane synchro. Meteorological Instrumentation	0-360^{0} to Ship's Head	1
Visibility	-	Manually operated decade switch	0-10 nautical miles	1

9.3 Description of Instrumentation and Operating Experience

a) Manual Circuits:

Environmental measurements of visibility cloud cover, ice cover, barometric pressure, air temperature and relative humidity are each entered via a decade switch on the bridge (see Figure 9.1). Most channels have a gain of 2, however because air temperature must cater for switch selectable + and - settings, its amplifier has a differential input and a gain of one.

Maintenance: No operating problems were encountered.

b) Wind speed and direction data were taken automatically from the ship's instruments (Figure 9.2). The anemometer gives an output of 0.07 volts/knot. This voltage was applied to an amplifier with a gain of 1 and a ref voltage of +5 to give outputs of +5 to +10 volts corresponding to wind speeds of 0 to 70 knots.

The ship's wind vane directional signal is passed through a synchro to analog converter. The converter output is then connected to the instrumentation system amplifier.

Maintenance: No operating problems.

9.4 Commentary and Recommendations

The environmental group of sensors, the CCTV system and a manually kept log combine to record environmental conditions surrounding the MV Arctic. With the exception of the automatically recorded wind parameters and the video tape, all other information (i.e., cloud cover, ice data, barometric data, air temp, relative humidity and visibility) is subject to inconsistent entry and in the case of cloud and ice cover and visibility, to the subjective views of the person entering the information.

Since there is no obvious way to overcome these shortcomings, care must be taken in the definition of operation procedures and in the design of sampling packages so that major errors in recorded data do not occur.

The significant parameter in the manually recorded group is ice cover. The use of a supplementary CCTV system is a good way to automatically record ice cover and should be considered for future systems. Consideration should also be given to recording wave action.

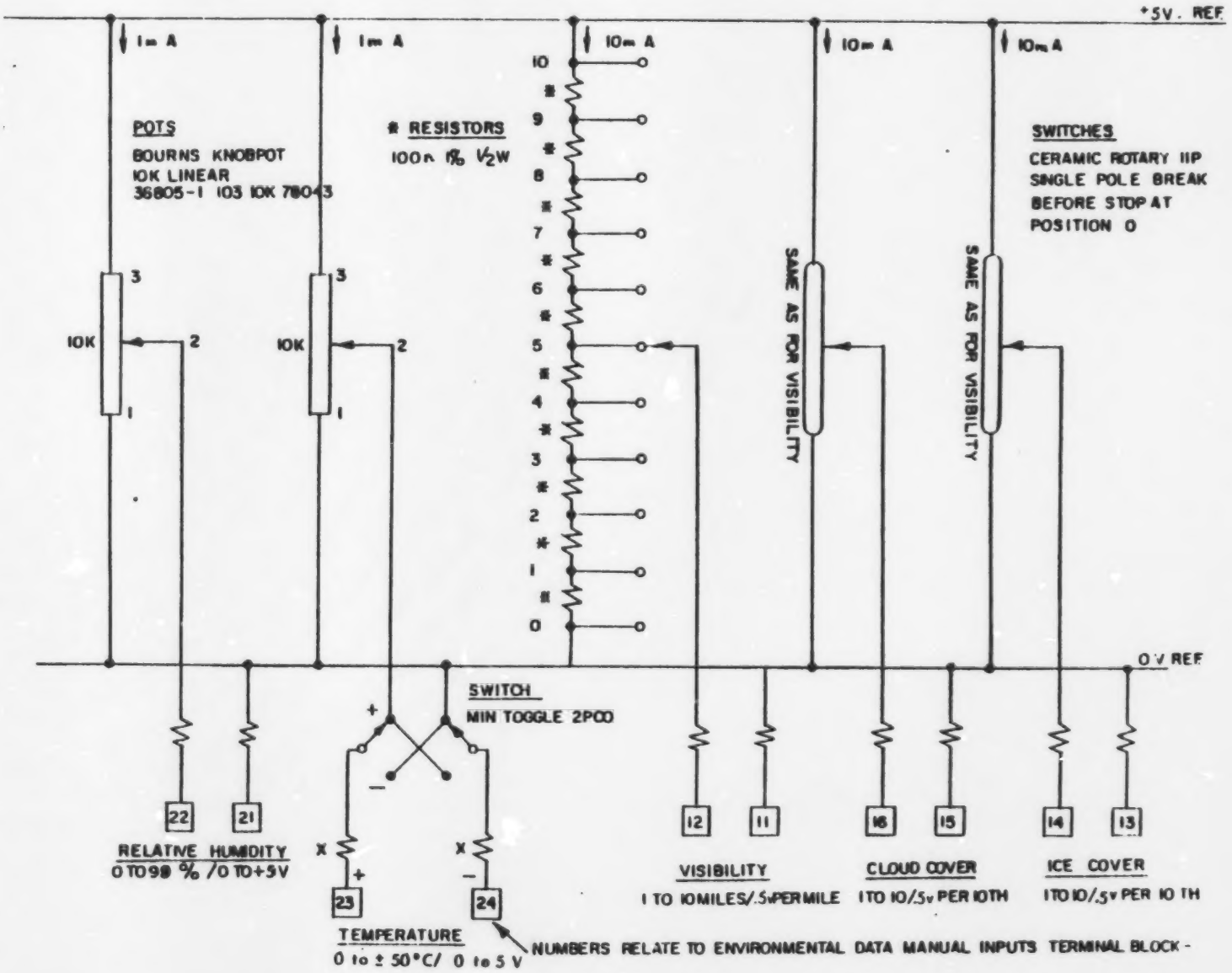


FIGURE 9.1 WIRING DIAGRAM, MANUAL INPUT CIRCUIT, ENVIRONMENTAL DATA

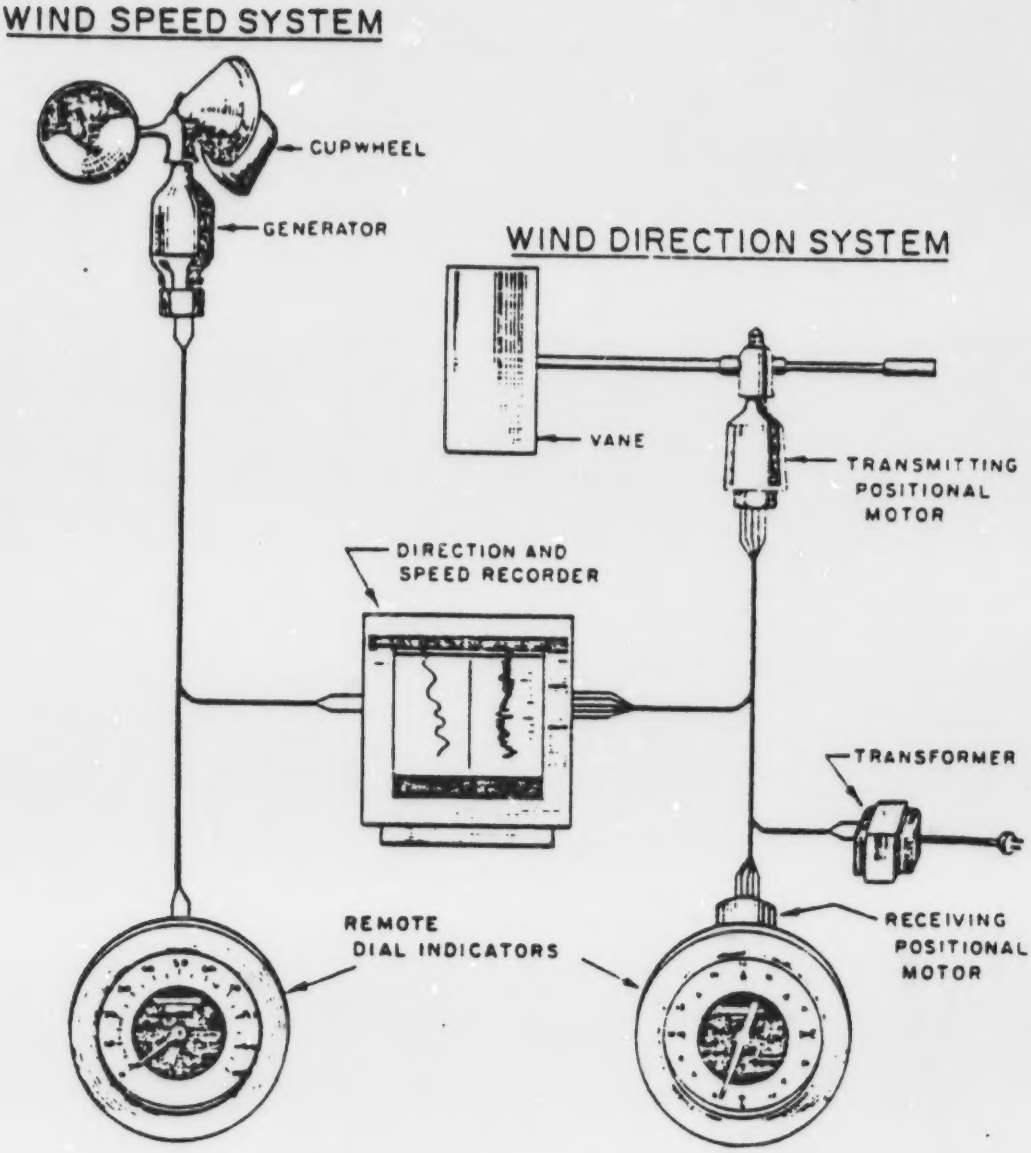


FIGURE 9.2 WIND MEASUREMENT SYSTEM ABOARD MV ARCTIC

10. JUNCTION BOX, DATA BUS AND INTERFACE PANEL

10.1 General

The sensor signals are accumulated at the junction boxes located throughout the ship (see Figure 2.2). The signals are transferred, when required, to the data bus and coupled to the computer via the interface panel.

10.2 Junction Boxes

There are seven junction boxes. Each is a watertight instrument enclosure housing up to three bins of amplifier cards together with their associated master cards and power supplies (see Figure 10.1). The junction boxes are located throughout the ship to minimize as far as practical the distance between a sensor and its amplifier card.

The +15V supply for each bin is provided by a Lambda Dual Output regulated power supply. Failure of a power supply triggers an "Invalid Data" alarm on the Interface Panel.

10.2.1 Master Cards

a) Description:

The master card provides a link between the data bus and the channel amplifier cards in its bin. It receives address and command signals from the interface via the databus and generates the necessary signals for the amplifier cards. Differential analog bus drivers on the master cards couple the amplifier card outputs to the data bus. CMOS chips are used for decoding addresses and switching data onto the analog bus.

b) Maintenance Experience:

Indication of faulty or failed cards:

Experience showed that a single unpowered master card, due to a failure of the +15V supply, can cause erroneous voltages across the whole data bus and prevent any sensible data from being sent to the interface. The problem of unpowered cards was rectified by using a spare line in the data bus to link relays in each box powered from the +15V supply to each master card. Any loss of power would cause a relay to drop out and the "Invalid Data" alarm to sound in the ship's laboratory. A faulty master card can also interfere with the data bus. Daily checking of test points on each master card is the only way to forestall problems stemming from this cause. Situations were also encountered where all channels in one bin gave incorrect printouts. This fault was usually due to one faulty amplifier card and occurs because all the amplifier cards in one bin share a common line to the master card signal input. Thus, one faulty card can drag down the line and prevent signals from going through. This fault can also occur with good amplifier cards if the sensor circuit is open for any reason.

The "cascade" aspect of the above faults, whereby one bad amplifier card can drag down a whole bin and one bad master card can drag down a whole bus, meant that the occurrence of a fault was not always obvious from a review of the printed output in the laboratory. A regular maintenance routine of checking voltage levels had to be instigated.

During the 1981 season a significant number of integrated circuits failed. This could be due to system ageing. CMOS chips are known to be intolerant to static charge, transient voltages and excessive circuit loading. They are most reliable when they are protected from these effects with TTL buffers and current limiters. On the MV Arctic most CMOS interfaces are buffered. However, with maintenance techniques which require frequent insertion and re-insertion of amplifier PCB's for fault finding, severe transients can occur which undoubtedly shorten the life expectancy of even the buffered CMOS chips. On the master card, one failed CMOS chip frequently destroys other good chips.

Additionally, there are hundreds of connectors strung out along the length of the ship. Each connector has from 10 to 30 pins creating a system with thousands of electrical connections. Because of the hostile environment, card replacement test routines and the contact material used, a certain number of contacts wore out and boards were readily shaken out of their connectors in rough seas creating additional stress on the transient sensitive CMOS circuits.

10.3 Data Bus (see Figure 10.2)

The data bus forms a loop round the ship connecting all the junction boxes and the interface. Thus, a single break in the bus will not cause any loss of data as there is still a route round the rest of the bus from any box back to the interface. The bus consists of an armoured cable containing 15 shielded twisted pairs of which only 13 are used. All lines are continuous round the bus except the "loop failure" lines "b" and "d" which are broken at a terminal box in the forepeak (port side) and joined to each other. The "loop failure" alarm tests for a continuous circuit round the loop, through all the boxes, to the terminal box on line b and back again on line d. Resistance of the lines round the entire loop is about 9 ohms. Breaks in the bus generally occur where the cables are soldered onto the plug connections at the junction boxes.

10.4 Interface Panel (Figure 10.3)

The Interface provides necessary coupling, level shifting analog to digital conversion, and some monitoring between the computer, remote junction boxes and the analog bus.

The main Interface is contained in a separate section of the computer rack and powered from dedicated ± 15VDC power supplies.

The following modules make up the rack:

- Utility module, providing telephone connection over the analog bus and a provision for the analog data monitoring.
- Analog to digital converter module, converting analog data to 10 bit offset binary format.
- Logic module, providing necessary sequencing and monitoring of computer signals.
- Driver modules No. 1 and No. 2, for buffering computer and logic module signals, providing as well the level shifting from +5V to +15V to obtain better noise immunity.
- Alarm and monitoring module, providing alarm circuits for alarms A, B, and C and initialization of "Enable," "Real/Peak" and "Clear" signals.
- Sound module, providing an audible alarm in the case of any alarm condition.
- Power module, indicating presence of the +5V power supply and providing fuses and ON/OFF switching for 110VAC line.

All connections but those for monitoring and telephone are on the rear of the rack. Two connectors are provided for the analog bus connections, one terminal strip for the power supply connections.

a) Utility Module

The utility module provides connections for a pair of battery powered telephones, via the analog bus, to any of the remote junction boxes. It also provides a buffered analog bus for monitoring purpose. This buffering utilizes an instrumentation amplifier in the same configuration as the one used in the A/D converter module.

b) Analog to Digital Module

The A/D converter module converts analog data coming from analog bus to a 10 bit offset binary format.

An instrumentation amplifier with gain adjusted to 1.0, serves as a buffer between the A/D converter and the differential voltage on the analog bus. This amplifier provides signals with ground reference for the A/D input. A 30 micro second time constant, low pass filter at the input reduces any high frequency noise.

The A/D converter outputs are buffered with 7406 type open collector buffers.

c) Logic Module

The logic module provides all necessary sequencing between the computer, A/D converter, alarm module and the junction boxes. Signals OUT BUSY and IN BUSY (active low) coming from the computer, are indicating outputs and inputs sequences. The logic module responds in turn with signals EXT GATE, which defines the time necessary to accomplish a chosen I/O operation and IN CLOCK which clocks the A/D output and DIS status into computer input interface.

d) Driver Modules

Driver modules convert 0-5V logic signal to 0-15V, 100MA signals to drive the analog bus addresses and controls, and to drive the LED visual indicators.

e) Alarm and Monitoring Module

The alarm and monitoring module provides a visual display of status of alarms A, B and C via LED indicators. Two push buttons are provided for the reset of alarms B and C. A relay monitors power supplies in the remote junction boxes indicating loss of power from a bin supply. A loop break of the analog bus is indicated. Four additional LED indicators, driven directly by the analog bus signals, indicate the presence of REAL and PEAK signals.

f) Sound Module

The sound module provides an audible alarm in the event of INVALID DATA, ALARM A, ALARM B or ALARM C. The SILENCE (disable) push button de-energizes the buzzer. The RESET push button re-arms the alarm.

g) Power Module

The power module consists of two fuses for +5V and +15V power supply, an ON/OFF switch for 115V, 60 HZ input power, and a LED indicator powered from +5V power supply to indicate POWER ON.

10.4.1 Maintenance Experience

Operations in 1979/1980 indicated thermal instabilities in several circuits when ambient temperatures went above 15°C. Cooling was required to maintain this temperature in the laboratory. The cause of the temperature sensitivity has not been determined.

In 1981 operators identified a problem with driver No. 2 which manifested itself in random pulses which caused the computer to crash. Cross coupling was suspected and was traced to two unterminated lines in the extension card used with the drivers. These lines were terminated through 2.4K resistors to ground and the manual zero line was also terminated. These modifications greatly reduced the frequency of interface problems.

10.5 Commentary and Recommendations

a) Junction Boxes:

The "cascade" effect found in both amplifier cards and master card circuits is an unfortunate feature of the system. It contributes to unnecessary down time for good channels and adds many hours to trouble-shooting practices. A redesign of both circuits is strongly recommended. Power supply and signal lines should be sufficiently isolated to permit the data channels to be independent of each other. Sensor conditioning cards should be able to be replaced with the power on without affecting other channels in a bin; these cards should also have short-circuit protection in the event of this type of sensor failure. Redundant power modules for the +15V supply should also be considered.

b) Data Bus:

The system redundancy offered by the loop data bus and distributed junction boxes may not be as attractive a feature as it was first thought to be. In fact, the bus was never severed although several times bus problems were traced to faulty connectors at the junction boxes. In future installations, consideration should be given to a system with a star configuration wherein all sensor cables are returned to a single control point. The advantages of a star configuration for shipboard installations include:

- Access in a single location to signal conditioning cards for every sensor circuit (see Figure 10.4).
- The possibility of improved address time if very rapid sampling rates are required.
- More efficient trouble shooting and maintenance procedures.

Wire runs from individual sensors into harness groups would require additional planning. However, in any cable run aboard ship the difficulty usually lies in defining the route while the size of the cable or harness is very much a secondary consideration.

c) Interface Panel:

The thermal instability in the interface panel is a system characteristic that should be resolved in any new installation. The nature of the shipboard operating environment dictates that where possible the electronic gear should have a reasonably broad operating temperature range. A more acceptable upper operating temperature limit would be +25° C.

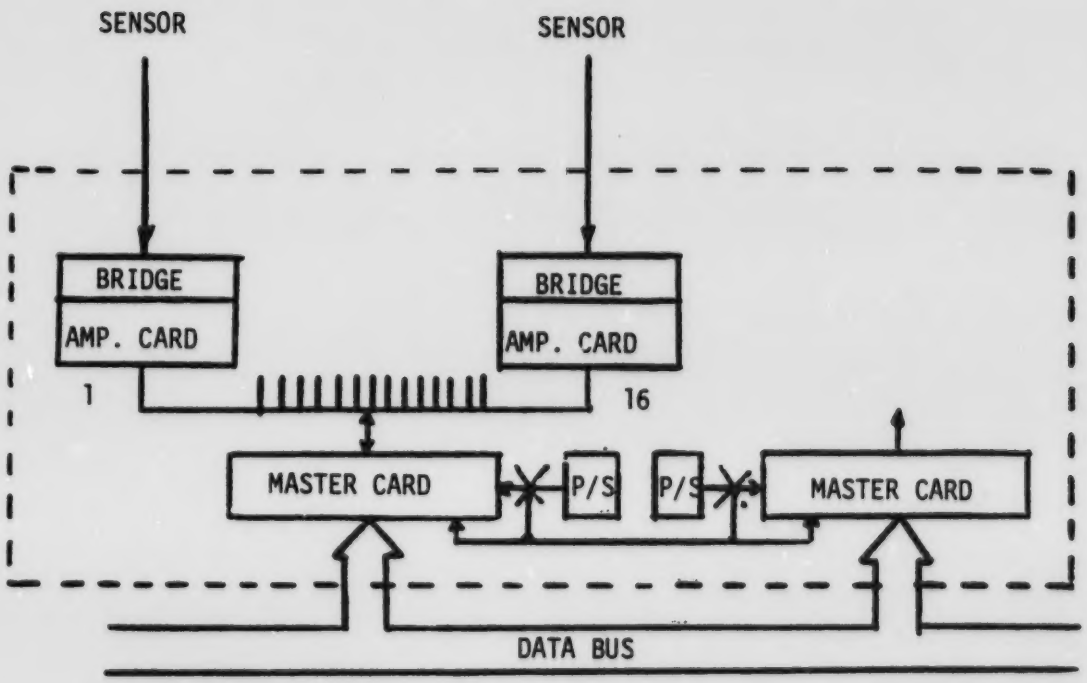


FIGURE 10.1 BLOCK DIAGRAM OF JUNCTION BOX

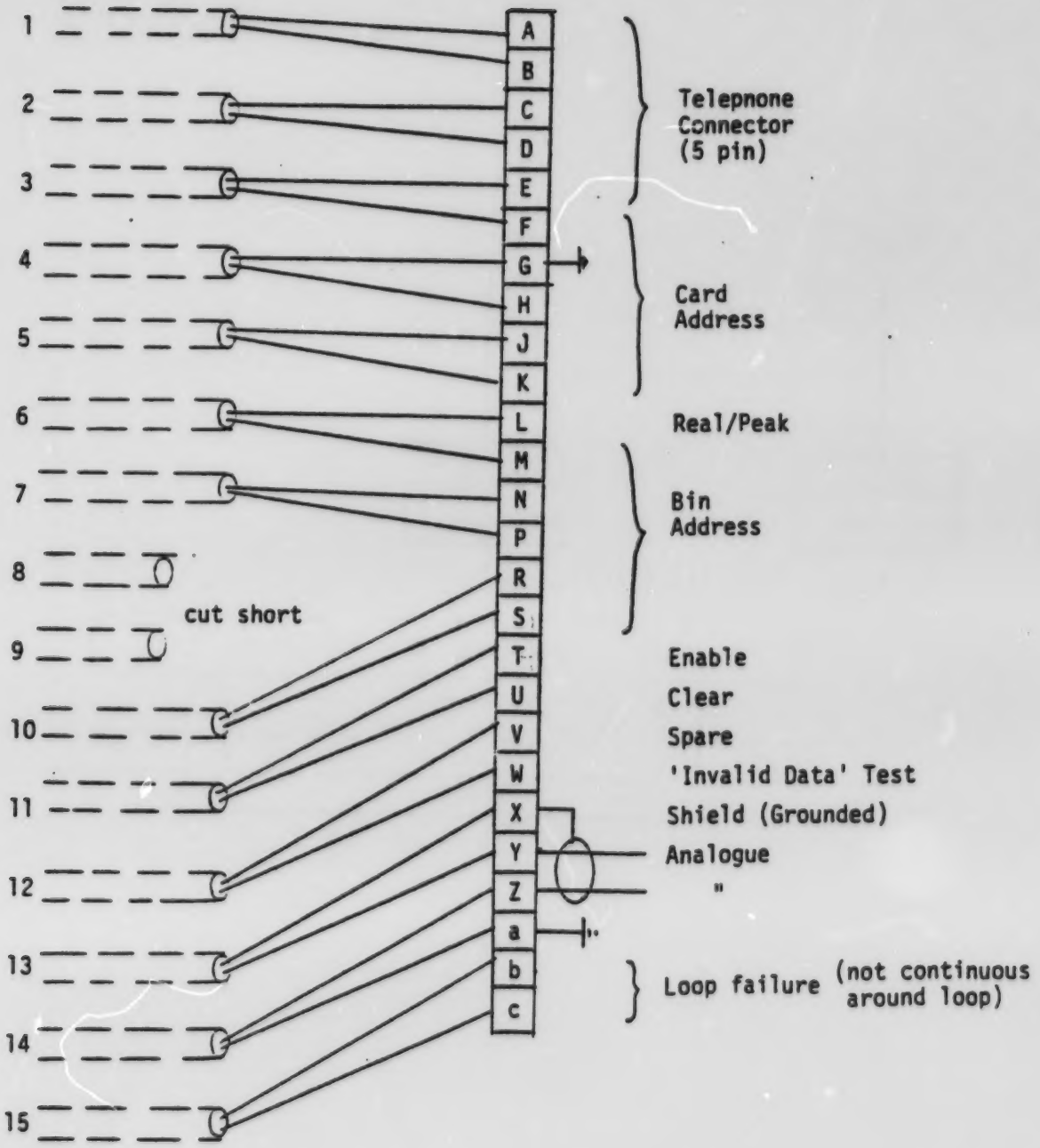


FIGURE 10.2 MV ARCTIC DATA BUS

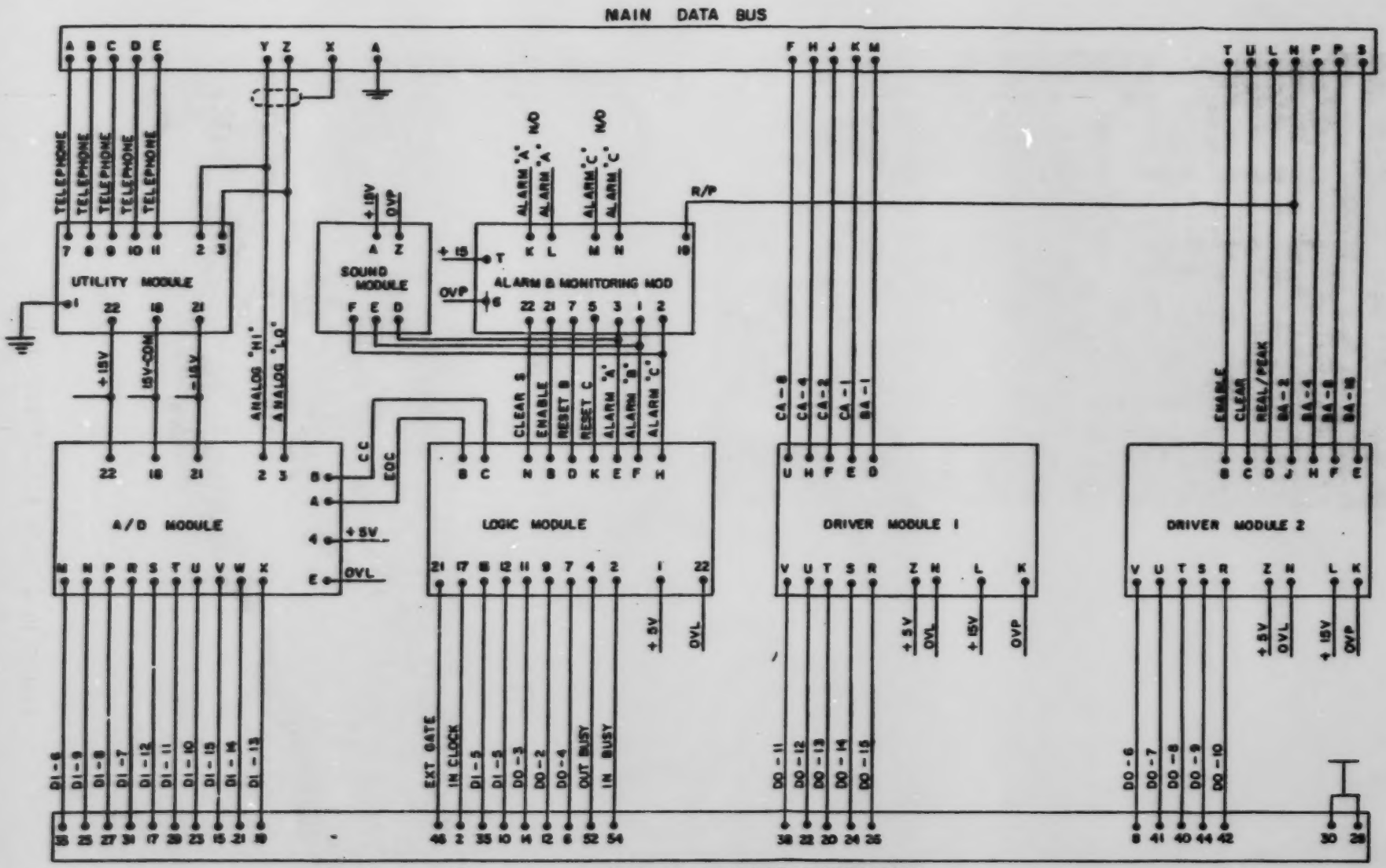
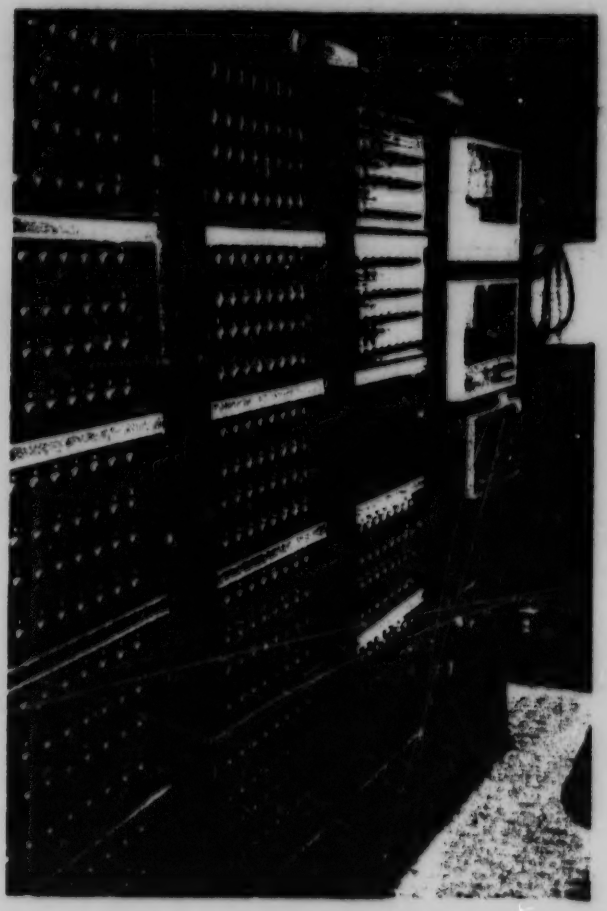


FIGURE 10.3 WIRING DIAGRAM OF INTERFACE PANEL

A 600 CHANNEL DATA ACQUISITION AND MONITORING SYSTEM INSTALLED ON THE TARSIUT ARTIFICIAL DRILLING ISLAND IN THE BEAUFORT SEA. THE SYSTEM WAS DESIGNED BY WJEC AND BUILT BY AN AFFILIATE, TERRASCIENCE SYSTEMS LTD.

THE SYSTEM PROCESSES INPUTS FROM STRUCTURAL, GEOTECHNICAL AND ICE FORCE SENSORS.



THE DOME PETROLEUM LTD. SSDC ON LOCATION IN THE BEAUFORT SEA. WJEC AND AFFILIATED COMPANIES SUPPLIED STRUCTURAL AND ICE FORCE SENSORS, ARCTIC GRADE CABLING, AND THE DATA ACQUISITION AND MONITORING SYSTEM.

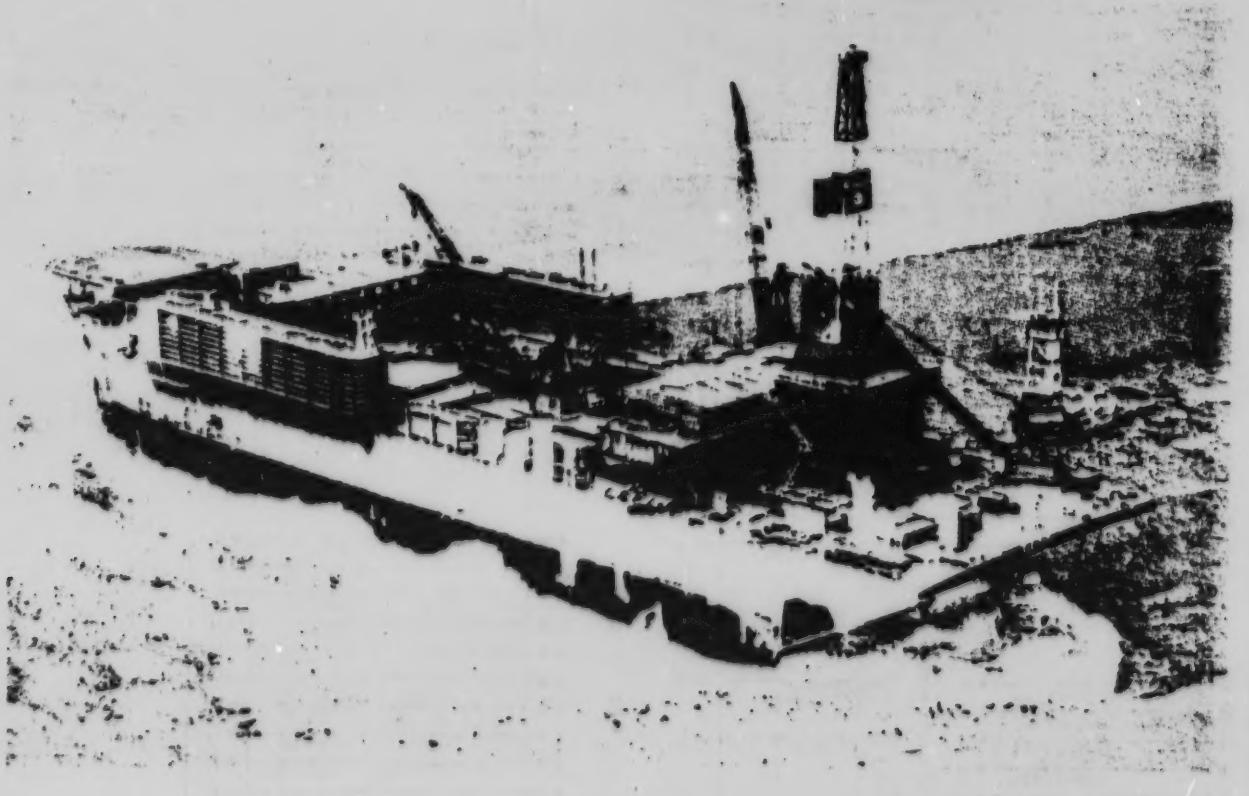


FIGURE 10.4 DATA ACQUISITION SYSTEMS

11. CONCLUSIONS

11.1 General

In addition to the operational experience and recommendations made in each section which relate to specific elements of the data acquisition system, there are other elements that affected the overall performance of the system which should be taken into account in any new installation.

a) System Capability

Fundamental to the effectiveness of any data acquisition system is the ability of the system to handle the load imposed upon it. In this instance it was discovered after installation that the total sampling capacity achievable was about one half of the expected capacity. The unique feature of systems such as this is that control is on a real time basis and hence the controlling unit (i.e., computer) must be able to handle all the requirements in the real time period allotted. It is therefore essential that the computer and its peripherals have the necessary clock frequency rating required of the data gathering program.

b) Operator Change

During the system's lifetime the responsibility for its operation passed through three different contractors. Because of this, a certain amount of relearning was required at the outset of each operational season and some of the previous year's maintenance experience was lost. This loss not only affected the up-time of the system but also the understanding of the quality of data that was recorded. The quality of the data is affected by the system performance hence a review of a systematically kept maintenance log is sometimes necessary to judge the degree of confidence to allocate to a particular data set. If operator change is necessary there must be adequate briefing at changeover and consistency maintained in written records.

c) Documentation

A system of this complexity, expected to operate for long periods without recourse to maintenance technicians, should have a substantial set of preventative maintenance documentation and trouble shooting guides for the on-board operator. No formal documentation of this sort was made available to any of the three contractors charged with the operation of the system. The first useful trouble-shooting guide was compiled late in 1981 by two on-board operators (see Appendix C). If further use is to be made of the MV Arctic system, this Guide should be expanded with particular emphasis on performance levels that might affect the accuracy of the recorded data.

d) Ease of Maintenance

The configuration of the system, a loop data bus joining seven remote junction boxes and the main interface panel, combined with the circuit design used, prohibited a full system check from being made at the laboratory location. Amplifier card and master card checks had to be made at the individual junction boxes. The advantage of this configuration was that it provided for bus redundancy in the event of a cable break. The complication of this design however was that it required the operator to perform daily checks at each of the remote junction boxes, frequently in most inclement weather.

11.2 Conclusions

Many factors affected the final design of the data acquisition system used aboard the MV Arctic, not the least of which were economic constraints and the unfortunate ramifications of having the company that designed most of the printed circuit boards go out of business before the system was fully operational. However this report must reflect on the system as it exists, its operational history and its comparison with similar systems now readily available on almost an off the shelf basis, in order to formulate recommendations for future installations.

a) Sensors Interfacing with Ship's Machinery

The majority of sensors that interfaced with the operating machinery of the ship experienced installation problems that prevented them from being operational for the 1979 season. Of those that were installed correctly two were not able to be calibrated by the system designers. One of these was eventually calibrated, the other was replaced with an alternative design. These problems occurred among the very important propulsion sensor set which diminished the usefulness of the data recorded by many other sensors in the system.

Recommendations 1. Provide adequate installation inspection.

2. Be sensitive to the possibility of the data acquisition system interfering with the host unit. If there is any concern on this point, develop an alternative means of acquiring the data.

3. Develop, test and document calibration procedures for all sensor circuits prior to installation.

b) Strain Gauges and Thermistors

The excessive operational failure rate among the Ailtech SG129 strain gauges is unacceptable in an installation requiring the reliability of a data acquisition system. The undefined use of the term "waterproof" by both the manufacturer and the system designers must in some way explain how these particular gauges came to be specified. The installation failure rates for these weldable gauges is also of concern. The reasons for the failure of the thermistors have not been documented as this portion of the system held a very low priority rating.

Recommendations 1. Only gauges designed specifically for underwater operation be used. These gauges normally come with special waterproof cable sheaths or with an additional waterproof sheath applied after assembly.

2. The use of bonded rather than welded sensors should be considered to reduce the possibility of damage during installation.

3. Consideration should be given to potting underwater cable connections to further reduce the possibility of moisture gaining access to cables and connectors.

c) Circuit Features Recommendations

i) Amplifier Cards

1. Cards should be able to be replaced with power on without affecting other data channels.
2. If filtering is required on a channel the REAL and PEAK feature of the circuit should not be lost.
3. Isolators should be incorporated in signal and power circuits so that a malfunctioning amplifier card or open circuit sensor does not affect other data channels.

ii) Master Cards

1. A faulty or failed master card should only affect the data channels in its bin. The card should be able to be replaced with the power on without affecting data channels other than those under its control.

iii) System Configuration

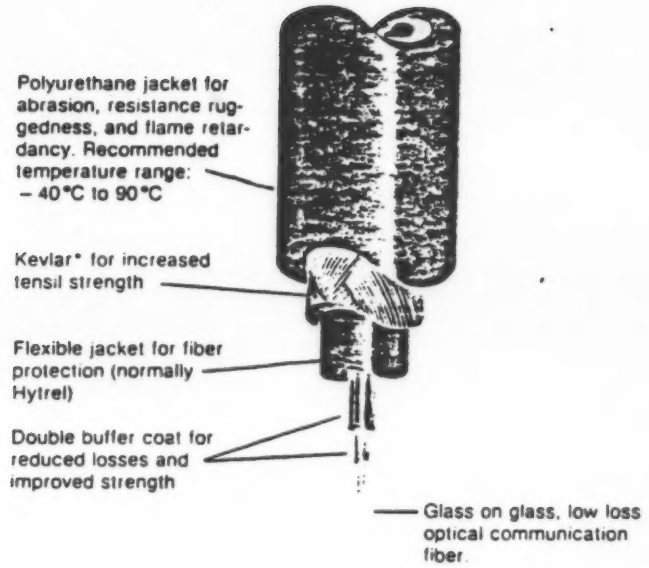
1. Whether a star or loop configuration is used for the data bus, all data channels should be able to be monitored from a central location. System diagnostics should alert operators of a broader range of failure location and types than is the case on the current system.

2. Although electrical interference was not a major problem aboard the MV Arctic, it has been on other shipboard installations. The use of Fibre optic technology should be considered for major cable runs. Fibre optics are being used extensively in new communications systems primarily for bandwidth, weight reduction and immunity to electrical interference (see Figure 11.1). They may be carried next to large current carrying cables with impunity. Optical cables in effect isolate electrical systems, eliminating the occurrence of ground loops which frequently plaque ships' electrical installations. Optical cables are also unaffected by sea water.

d) Cost Considerations

The recommendations given above may result in a more expensive initial installation. However when one considers the degree of reliability and level of performance necessary for the system to be useful, and the cost of trouble-shooting the current system over the three operating seasons, increased initial costs may well be fully off-set by reduced operating costs and the logging of more accurate and useful data.

Additionally, since the design of the MV Arctic system several similar data acquisition systems have been installed on ships (Pierre Radisson, Polar Star, Canmar Kegoriac). Manufacturers of system components now have off the shelf items that have been service tested and which include desirable features not now included in the MV Arctic system. The availability of standard components would tend to reduce initial costs of the enhanced system recommended.


Polyurethane jacket for abrasion, resistance ruggedness, and flame retardancy. Recommended temperature range: – 40°C to 90°C
Kevlar* for increased tensil strength
Flexible jacket for fiber protection (normally Hytrel)
Double buffer coat for reduced losses and improved strength
Glass on glass, low loss optical communication fiber.

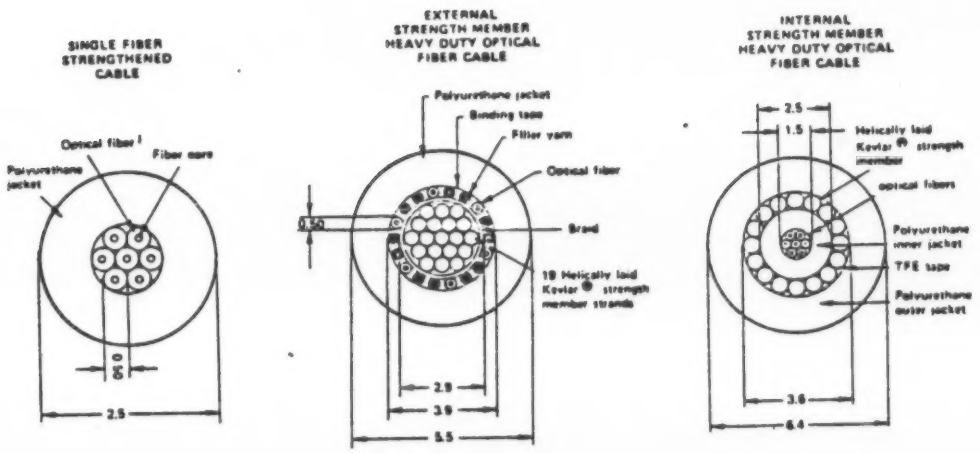


FIGURE 11.1 TYPICAL MULTICHANNEL FIBRE OPTIC COMMUNICATIONS CABLES

APPENDICES

Source: TP 3632 Vol I (Fenco)

A. INVESTIGATION OF STRAIN GAUGE PROBLEMS

Strain gauge drift, and eventual failure, has been a problem with the MV Arctic Data Acquisition system since it was installed and has necessitated replacement of gauges on several occasions. During such work water has been found in the cables of the failed gauges and the seepage of water into the cables is thought to be responsible in some way for the drift and failure of the strain gauges. This report describes an investigation made in July/August 1981, of the strain gauge problems, identifies the probable cause, and suggests possible solutions.

Strain Gauge Drift

Each strain gauge is connected as one arm of a resistance bridge with the other resistors being mounted inside the boxes in the forecastle (see Figure A.1). The strain gauge and 120 ohm resistor form a voltage divider producing about 5.0 V at their mid-point (pin 16), while the two 1 Kohm resistors produce about 5.0 V at pin 15 which, with the balance pots, can be adjusted to exactly equal the voltage on pin 16. When this occurs the bridge is said to be balanced, the input to the differential amplifier is 0.00 V, and an output is produced equivalent to zero microstrain. Any changes in strain gauge resistance will then cause a change of voltage at pin 16 and consequently a strain reading at the output. If this strain gauge resistance change constitutes a permanent offset it can be balanced out by adjusting the voltage at pin 15 so that it equals the new voltage at pin 16. The range of adjustment of the pin 15 voltage is typically from 4.90 V to 5.10 V, the actual values depending on the voltage regulator output on each card, and a strain gauge is no longer useable when its resistance has changed such that the pin 16 voltage is outside this range.

The pin 16 voltage can be checked by connecting a voltmeter between the amplifier card white test point and ground. Such a check of all strain gauge channels on August 8, 1981 showed that the strain gauges considered to have failed had test point voltages which exceeded the upper limit of the balance adjustment. Thus failure of the strain gauge can be attributed to a permanent increase in the resistance of the strain gauge arm of the bridge.

Resistance Changes

Resistance changes in the strain gauge arm of the bridge can be caused by actual strains, leakage to ground through the electrical insulation, or corrosion of the strain gauge and/or connections.

Strains in the hull cause a change in strain gauge resistance, consequently a dent (i.e., a permanent strain) will cause a permanent change in the strain gauge resistance. However, the resistance changes are very small, for example, a strain of +2000 microstrain will increase the strain gauge resistance by 0.5 ohms and produce a 0.01 V change at pin 16, so cannot be responsible for the large strain gauge drifts detected.

Resistance to ground with working strain gauges is generally in excess of 20 Mohms and resistances less than this have often been regarded as indicative of a suspect strain gauge. Leakage to ground and leakage between the conductors will produce an apparent decrease in the resistance of the strain gauge arm of the bridge, and a resistance as low as 1 Mohm will only produce a 0.014 ohm change in the 120 ohm value of the strain gauge resistance. Consequently, while low leakage to ground may be indicative of problems such as water getting into the cables, it is not in itself the cause of failure of the strain gauge circuits.

Corrosion of the strain gauge or its connections reduces the thickness of the wire and consequently produces an increase in resistance of that part of the circuit. Eventually the corrosion may go right through the wire causing an open circuit, as has been found with some failed strain gauges. Thus, corrosion in the strain gauge circuit will produce resistance changes the same as those associated with failed strain gauges.

Corrosion

To check for corrosion the forepeak tank was opened up and an inspection made of some of the failed strain gauges. On the six strain gauges inspected there was no sign of rust nor any rust on the surrounding metal of the hull. However, when one of the cables was cut water ran out and other cables were damp inside. By carefully cutting away the insulation and the waterproofing, it was possible to examine the connection between the cable conductors and the strain gauge lead at the point of connection to the cable conductors (Figure A-2). This corrosion probably occurs because the presence of salt water together with the contact of two different metals and the current passing through them causes an electrolytic reaction.

Discussion

The suggested scenario for strain gauge drift and failure is therefore that water seeps into the cable and runs down to the strain gauge connections where it gives rise to corrosion. However, the presence of water is not on its own an indicator of strain gauge failure. The criterion for strain gauge operation is that its measured resistance, considering the other bridge resistors in parallel, should be less than 116 ohms. An alternative quick measurement is to check that the voltage between the white test point and ground is less than 5.10 V. Using this voltage measurement, 15 rejected strain gauges were considered good and added to the sampling pattern, and checks a month later showed that all but one were still operating correctly.

Increasing the range of the balance adjustment may bring more strain gauges into use, although this may only be a temporary solution if the strain gauge circuit continues to increase in resistance and becomes open circuit.

To prevent the failure of strain gauges the obvious answer is to use waterproof cables but this may prove expensive. As the problem appears not to be caused simply by water in the cable but by the water running down to the strain gauge connections, a partial solution might be to put a loop in the cable so that it hangs down below the strain gauge and forms a water trap, thereby preventing water in the cable reaching the strain gauge connections. However, if the water moves through the cable by capillary action and not simply the force of gravity, then such a loop in the cable is unlikely to have any effect.

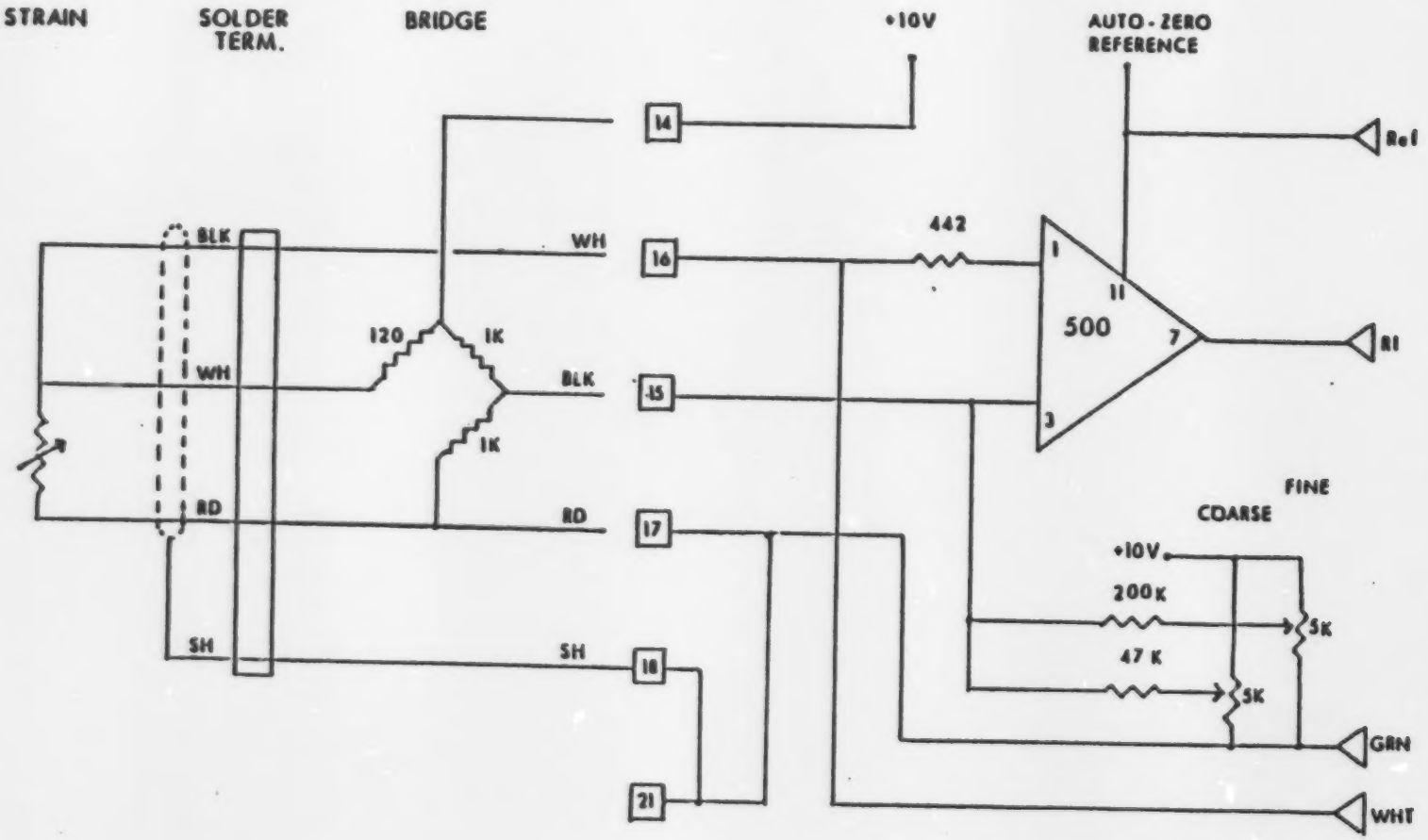


FIG. A.1 STRAIN GAUGE BRIDGE CONFIGURATION

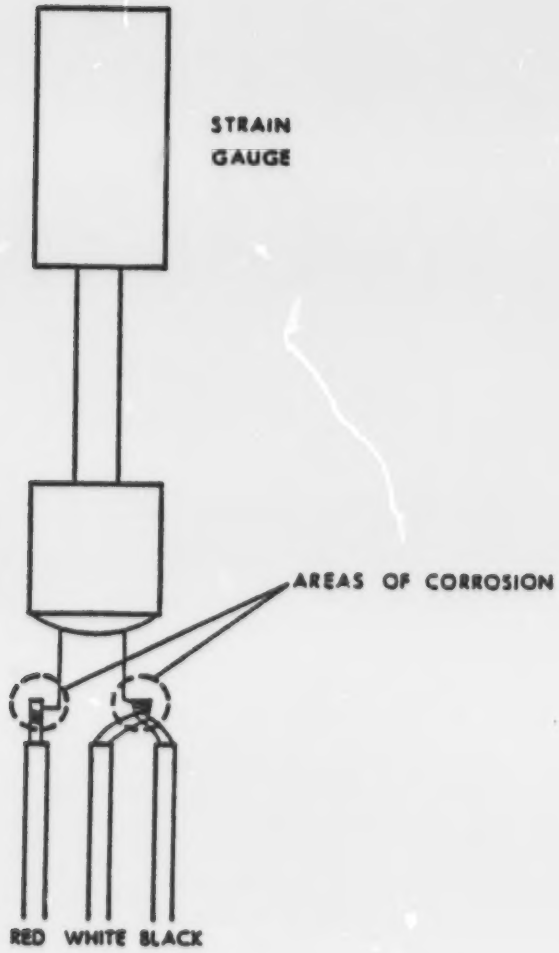


FIG. 2 CABLE CONNECTIONS TO STRAIN GAUGE SHOWING AREAS WHERE CORROSION OCCURS.

Source: TP 3202 Vol I (Fenco)

B. CALIBRATION PROCEDURE FOR SHAFT TORQUE SENSOR

Torquemeter (Channel 208)

When a torque is applied to the shaft, shear stresses are produced at the surface of the shaft and along the shaft. The tangential shear stress causes a twist in the shaft and a consequent shear strain (Figure B.1).

Distortion of Surface Element by a torque, T.

Resulting compressive strains (→←) and extensive strains (←→) produced in the strain gauge bridge.

Figure B.1: A Torque, T, will twist the shaft causing a shear strain.

$\gamma = \frac{\Delta \ell}{\ell}$ This produces: Compressive strains, $-\Delta S = -0.5\ \gamma$

Extensive strains, $+\Delta S = +0.5\ \gamma$

The shear strain along the shaft, however, produces a negligible strain because of the considerably greater rigidity of the shaft in this direction. Thus the basic equations are:

$$T = \frac{I}{R} \cdot G \cdot \gamma$$

where T = Torque (ft. lbs.)
R = Shaft radius (ft.)
G = Shear Modulus - 1709×10^6 lbs./sq. ft.
γ = Angular Strain (i.e., Shear strain)
I = Torsional Modulus - $\pi d^4/32$
and d = shaft diameter - 1.75 ft.

There is a linear relation between torque and strain:

$$T \text{ (ft. lbs.)} = 1800\gamma \quad (\mu S)$$

The extensive strain, ΔS, produces a change, ΔR in the strain gauge resistance, R, given by:

$$\Delta S = \frac{\Delta R}{F.R}$$

Where F = gauge factor

For the purpose of these calculations the gauge factor is assumed to be 2.0, and R = 120 ohms. Therefore:

$$\Delta R = 240 \cdot \Delta S = 120 \cdot$$

When the shaft is subjected to a certain torque the changes of resistance, ΔR, in each arm of the full strain gauge bridge produce an output signal out equivalent to that produced by a 1/4 bridge with a resistance change, $\Delta R'$, where

$$\Delta R' = 4. \Delta R$$

During the calibration procedure shunt resistors are connected across one arm of the bridge to simulate a strain by producing a resistance change $\Delta R'$.

Sample Calculation:

Shunt one arm of bridge with a 200K resistor. This gives $\Delta R' = 0.0714774$ ohms. This gives a signal out equivalent to a full bridge with:

$$\Delta R = \frac{\Delta R'}{4} = 0.0178694 \text{ ohms}$$

This would be produced by a shear strain:

$$\gamma = \frac{R}{120} = 149.10^{-6}$$

The corresponding torque would thus be:

$$T = 1800 \times 149$$

i.e., $T = 268.10^3$ ft. lbs.

Calibration of the Torquemeter is done in two parts:

'Zero' Offset

Because of S/G drift and drifts in the F.M. telemetry system, zero torque does not product 0 volts output from the torquemeter, so it is necessary to establish the 'zero' offset. To do this, it is not possible to simply take the reading when the shaft is stationary because friction in the bearings always results in a residual torque when the shaft stops. To overcome this, the shaft must be rotated slowly (using the turning gear) for one revolution, first one way and then the other, while readings are taken every minute. The average of these readings can then be taken as the output level for zero torque.

Slope

Due to the linear relationship between strain and torque, changing the S/G resistance to simulate a certain strain is equivalent to simulating the corresponding torque. This is done by shunting one arm of the S/G bridge on the shaft with known resistors. These should be connected across terminals 'b' and 'c' as shown in Fugure B.2.
Recommended shunt resistors, and corresponding torque values, are:

1 M Ω	52.10^3 ft. lbs.
400 K Ω	133.10^3 ft. lbs.
200 K Ω	268.10^3 ft. lbs.
150 K Ω	358.10^3 ft. lbs.
100 K Ω	537.10^3 ft. lbs.
75 K Ω	717.10^3 ft. lbs.
66 K Ω	815.10^3 ft. lbs.

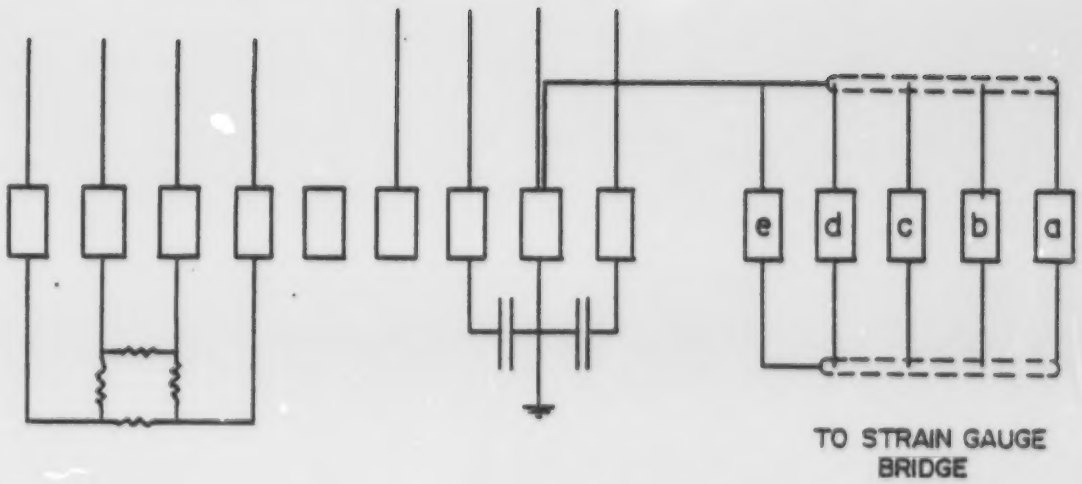


Fig. B.2 Torquemeter Connections on the Shaft for calibration connect shunt resistors across b and c.

Source: TP 3634 Vol II (Arctec)

C. OPERATOR'S TROUBLE-SHOOTING GUIDE

INTRODUCTION

When a fault occurs in the data acquisition system, it becomes evident in one of many system components first. In many cases this first clue that something is amiss occurs in a component that is far removed from the component at fault. In these cases we first see a symptom of the fault and then, after trouble shooting the system, we come across the origin of the fault. With the origin of the fault identified the problem is easily cured provided replacement parts are available. The following trouble shooting guide identifies symptoms of a fault, guides the operator to the unit that caused this symptom and describes the action required to cure the fault. The guide is based on trouble shooting techniques developed by two operators during half of the 1981 operating season.

The guide is formatted in two parts. In the first part, the symptom/fault/cure guide is provided. This is divided into sections lettered A through G as follows:

A - Tapedrives
B - Interface Modules
C - Transducers
D - Computer
E - Terminal
F - Master Cards
G - Amplifier Cards

Part two is a general maintenance guide providing the operator with recommended schedules and techniques for preventative system maintenance. This is sub-divided into sections denoted by GM.

PART 1 - FAULT FINDING

Symptom	Fault/Action
A. Tape Drives	
(1) Tape drive loses vacuum, vacuum pump shuts down.	(1) See GM.3
(2) Starting up drive results in tangled tape with no vacuum.	(2) See GM.3
(3) Drive stops moving during data acquisitions (accompanied by computer crash) but vacuum stays up.	(3) See D.1
B. Interface Modules	
(1) Invalid data light flashes on and off and latches alarm on.	(1) (a) Faulty relay in one or more boxes. (b) Power supply off in a box, maybe faulty key switch.
(2) Significant difference between PEAK and REAL mode oscilloscope traces from A/D test point with continuous scan test program. Typically PEAK trace different level than REAL trace with large rising and falling edge spikes.	(2) See GM.1 (and illustration)
C. Transducers	
(1) Strain Gauges	
(a) No longer able to balance gauge, typically amplifier saturated at + 12 V dc.	(1) (a) Modify coarse balance controls by inserting a 10 KΩ resistor across R55.

Symptom	Fault/Action
C. Transducers (cont'd)	
(1) (b) Strain gauge drifts into amplifier saturation daily.	(1) (b) Gauge is most likely wet and will continue to drift erratically until the ship's ballast is altered and the gauge is allowed to dry out.
(c) Unable to balance gauge despite extended balance modifications of C (1) (a).	(c) Damaged gauge may recover at a later date if a moisture problem.
(2) Roll/Pitch Gyro	
(a) Noisy signal especially at one roll or pitch angle.	(2) (a) Faulty potentiometer with crack or dirt on resistive element - clean with contact spray.
(3) Accelerometers	
(a) Output drifts extensively.	(3) (a) Check transducer by switching amplifier cards from another accelerometer - if drift stays with suspect transducer, replace accelerometer.
D. Computer	
(1) Run light goes out (computer crash).	(1) (a) Sampling rate and pattern incompatible with computer, reduce sampling rate.
	(b) Noise on computer interface, specifically, driver module #2: check for improperly terminated logic lines (design flaw)-see GM.2
(2) Computer main frame overheating.	(2) Clean fans, open porthole to keep lab below 70°F.
(3) Computer logs all gauge channels at approximately -250 micro strain or logs all channels in one bin at -250 micro strains.	(3) Master cards not being addressed (sampling bus level of 4.53 volts) - see F.2.
E. Terminal	
(1) "End of paper" fault does not clear after paper refilled.	(1) Turn terminal off then back on with power switch.
F. Master Cards	
(1) Card tests okay in lab but is not being addressed as evident from CE (card enable) test point remaining low.	(1) Faulty address switches on M.C. burnt out IC2: check in lab with all possible logic combinations on block address.
(2) Not all amplifier cards being addressed or amplifier cards being addressed too many times per second.	(2) (a) Short in address switch area.
	(b) Burnt out IC1 or IC14.
	(c) Poor or shorted contacts on edge connectors in bin resulting in incorrect addressing - pull and re-insert card for a possible temporary fix.

Symptom	Fault/Action
G. Amplifier Cards	
(1) Card not being addressed as evident from test point CA (card addressed).	(1) (a) Check Action F.2. (b) Check IC2 by bench testing with all card address combinations.
(2) REAL output shifts a maximum of $\frac{1}{2}$ volt, remains stable then intermittently shifts again.	(2) Auto-zero circuit is cycling, disable circuit by tying ZC to ground on M.C. (remove IC5) or jumper reference voltage on amp card to level pot.
(3) Card addressing works in one slot but not another.	(3) See F.2.

PART 2 - GENERAL MAINTENANCE GUIDE

GM.1

All amplifier and master cards should be checked with the logic probe for correct addressing periodically.

(a) Put the computer in the scope TEST mode and set it up to address all cards consecutively. Periodic pulses should be seen at amp card test point CA and master card test point EN.

(b) With the TEST program addressing individual channels check for clean pulses on the analogue bus (test point on A/D unit). These wave shapes are illustrated in Figure C.1. Note that both in the REAL and PEAK mode the shapes should be similar and at the same levels. If this is not the case but test points CA and EN checked okay in (a), then the logic gates controlling the analogue switch are most likely at fault (IC.3).
Note also that if no amplifier card is in the addressed slot a distorted pulse is also observed.

GM.2

In the 1981 operating season a major problem was the computer stopping while in the data acquisition mode. The problem was discovered to be primarily with the logic interface in driver module #2 where improperly terminated logic lines were picking up noise and confusing the computer, causing it to crash, sometimes erasing the acquisition program. It was also discovered that, subsequent to interface modifications, the system would periodically crash if the room temperature rose above 80°F. While troubleshooting the system for the interface logic line problem a number of interesting effects were observed which may be useful in future interface problems:

(1) Removing the bus via the two multi-conductor connectors on the interface module invariably stopped the system from crashing. It is believed that the bus switching transients provided a source of noise to act on the floating logic lines causing the system to crash. Removing this noise source stopped the problem.

(2) Putting an extender card on driver module #2 also reduced the number of computer crashes by moving the module farther away from the noise source.

(3) The tape drive unit could be taken off line, shut down and hence isolated from the system without the computer's acquisition program stopping. This proved that the tape drive units were not causing the computer crashes.

(4) Adjusting the period of oscillator U6 on the interface logic module (potentiometer P1) seemed to affect the system's reliability. A setting of 35 microseconds produced the most reliable results. This setting also appeared to shift possibly due to mechanical vibration or thermal changes.

TAPE DRIVES

GM.3

The biggest enemy of the Ampex tape drives is the dust from the ore that is everywhere while loading in Nanisivik and Antwerp. As a result the units should be cleaned every day while in ice as instructed in the Ampex manual.

In addition, all hose connections should be checked for a tight fit, especially the 1/4" ID clear hoses for a tight press fit.

GM.4

Note that if the Ampex tape drive #0 becomes inoperable, programs can still be loaded from unit #1 by changing its address to 00 (and unit #0 to 01) in the back of the rack.

GM.5

When trouble shooting CMOS IC's beware that a logic "high" input has been known to supply sufficient supply voltage to a damaged chip to keep it operational. Obviously if that "high" logic level goes low the chip becomes inoperable.

GM.6

CMOS IC's are not fully checked unless all outputs have been shown to be capable of toggling between logic 0 and logic 1.

GM.7

CMOS logic boards should not be removed with the power supplies on nor should the logic be driven by external logic while the board's supply is off. Obviously this ideal condition is virtually impossible to achieve with the physical arrangement of the systems. Nevertheless, it is advised that, whenever feasible, the power supplies be shut down while removing cards, especially while doing extensive repairs.

VIDEO

GM.8

In the 1981 fall operating season the pan-tilt T.V. camera system was non-operational due to excessive corrosion of components in the "environmental" housing. This occurred primarily because of salt water spray entering the housing through ventilation holes while in heavy seas over a period of years. A second camera was mounted in the look-out room on the fore-mast. Note also that two video co-ax cables were installed on the starboard side for the cameras used during the dedicated trials in November 1981. These cables may stay intact for several years and be useful as a back-up some day.

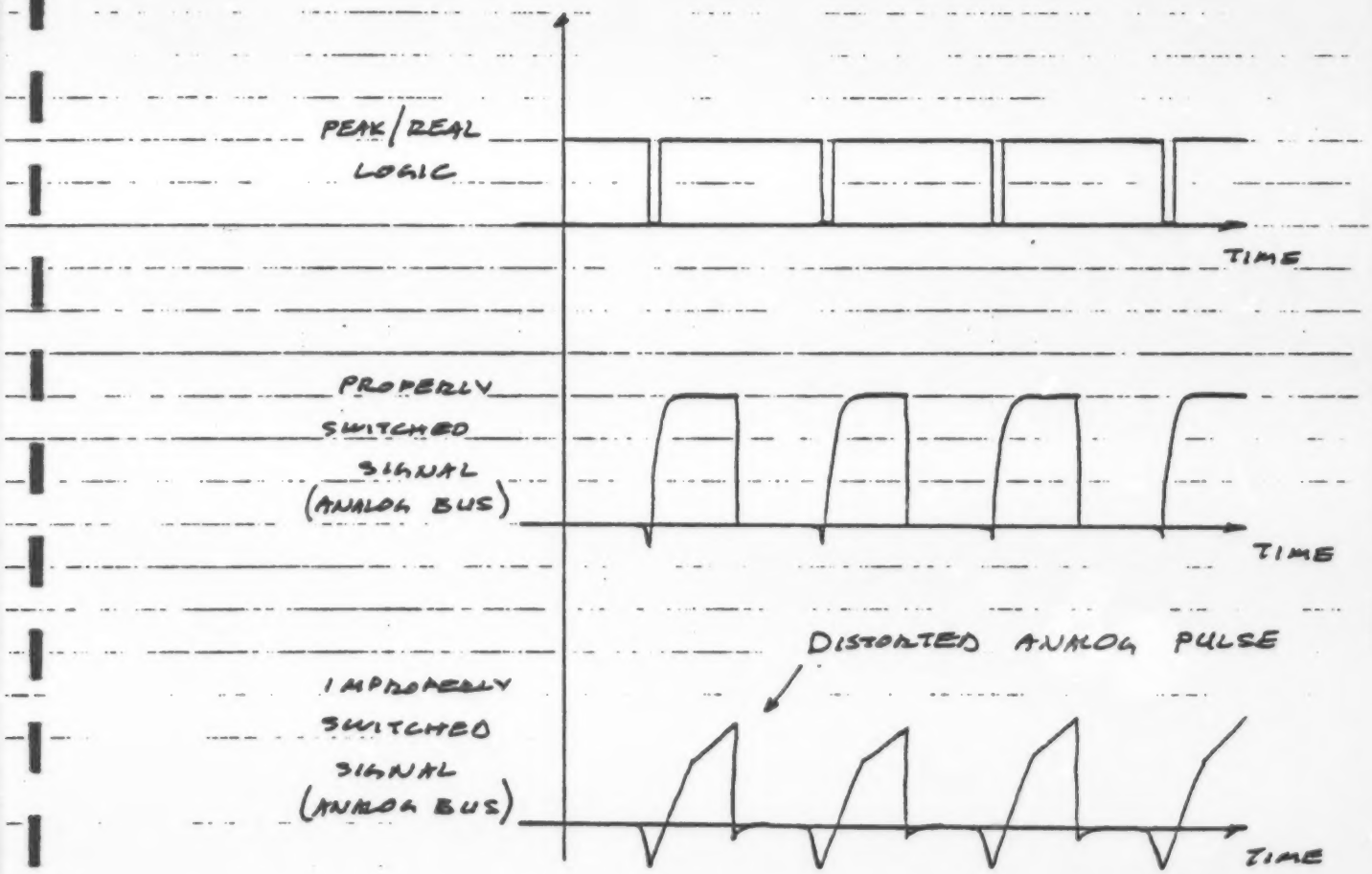


FIGURE C.1. DISTORTED SWITCHING ON ANALOG BUS